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I. Some factors affecting the production of insulation board. II. The development of the commercial production of refrigeration board and pressboard

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I. SOME FACTORS AFFECTING THE PRODUCTION OF INSULATION BOARD. II. THE DEVELOPMENT OF THE COMMERCIAL PRODUCTION OF REFRIGERATION BOARD AND PRESSBOARD.

By

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I

INTRODUCTION

The forests of the United States are rapidly being depleted. They have been reduced from eight hundred and twenty-two to four hundred and seventy-one million acres during the past two centuries (48). Over seven million acres are destroyed by fire annually (3). This condition is very alarming for it not only causes a shortage of lumber but it also affects the drainage and rainfall of the country. Any substitute for lumber would be expedient.

The total available wood of all kinds in the United States in 1923 was seven hundred and forty-five billion cubic feet. The annual consumption amounts to twenty-five billion or slightly less than one thirtieth of the total supply (48).

The United States uses more wood products than any other nation in the world. This nation alone uses over one-half the lumber, over one-half the paper, and about two-fifths of all the wood used in the world. At present United States uses more than four times as much as it replaces. The principal food growing region imports 77 per cent of the lumber consumed while the principal manufacturing region imports 68 per cent (15).

The pulp-wood industry has gradually shifted to Canada and the Pacific North-West, but, in spite of this moving to sources of raw material, it faces a shortage of trees for pulp production. The supply of timber constantly decreases in spite of reforestation and other remedies. Substitutes for wood have been introduced as possible remedies for this timber shortage. Several types of rigid insulation of high efficiency have been produced. The most successful materials commercialized, so far, proved to be those containing a large number of air cells of small size separated from one another. Cork, hairfelt, wood, vegetable material of various sorts, and cellular or fibrous mineral products possess this property. Among the many boards on the market may be named Celotex (65), Insulite (37), Maizewood (37), Masonite (4), Maftex (37), Insoboard (14), Sheet Rock (37), Ten-test (37), and Nu-Wood (63).

The importance of this new industry is realized by the fact that the present production of insulation in the form of boards, both rigid and non-rigid, has reached five hundred and twenty-five millions of square feet annually (49). The estimated saturated market for materials of this nature is ten billion square feet.

The foregoing facts show that synthetic lumber does have an important place to fill in our economic scheme. And it is only natural to study the conditions necessary for its increased production.

Since the cornstalk is so abundant and since it furnishes a good raw product for synthetic lumber much study has been given to the development of this plant.

Three types of lumber can be secured from the cornstalk, first, the insulation wall board, second, the light refrigeration board, and third, the strong, dense pressboard.

The first board is applied in place of the wooden sheathing under siding. It presents a more rigid wall and one that has about four times the heat insulating value of pine board. This insulation board is also used as lath and for insulating ceilings of large factories.

The refrigeration board is used where low density and low heat conductivity are required. This board is very useful for refrigerators and for insulating cold storage rooms.

The pressboard possesses great strength and high density. It can be used for book covers, electrical insulation, for light furniture, for automobiles, and for interior wood work in dwelling houses.

II

REVIEW OF PREVIOUS INVESTIGATIONS

A. Insulation Board

The applications of thermal insulation are not new, but the manufacture and development of efficient insulation are truly products of the last two or three decades. Insulation of dwellings has been a practice ever since buildings have been constructed. The primitive man's house, the earth dwelling with its hard rammed walls and thickly thatched roof, served to prevent the loss of heat long before the knowledge of heating was at hand. As civilization advanced the art of building also advanced, for it was at this stage that the masonry house was introduced. These houses did provide for some heat insulation but were built mainly to prevent the rain and snow from penetrating the space within.

One of the first attempts to utilize insulating materials was discussed by Evelyn in 1664 (2). This author stated that the poorer classes of spain used strips of bark from the cork oak to line their houses, making them warm and preventing the moisture from collecting on the walls.

The use of air as an insulator has been known for a long time. The frame house was developed with the idea that dead air spaces could be maintained between the inside plaster walls and the outer wood work. Wood, however, shrinks and contracts with changes in humidity, causing many cracks in the frame construction. Since plaster is a poor insulator, the heat of the room was carried to the outside atmosphere. In those days, keeping a house warm was nothing more than supplying a surplus amount of heat to replace that which escaped to the outside.

During the next decade the heat losses were partly reduced by placing sheets of paper under the weather boarding.

Refrigeration engineers installed insulating materials into both the refrigerator car and the cold storage room in order to preserve foods. Later, architects found that by applying a layer of good insulating material to the walls of a dwelling, a large amount of fuel could be saved and that such insulation would reduce the size of initial heat equipment.

A large industry grew up to meet the demand for an efficient insulation. Granulated cork, a waste from the stopper industry, pressed into the form of boards or slabs became one of the earliest types of rigid insulation (38). Numerous patents (39) were taken out before 1900 for the utilization of a host of other materials, but the production of thermal insulation of low conductivity did not become a large scale reality until 1916. Since 1916, over two hundred patents were issued covering new developments and inventions occurring in the insulating wall board industry. Among this number were rigid, non-rigid, and loosely bound types. The production of the rigid board type insulation has been largely dependent upon the development of suitable and economical machinery for its manufacture.

Since 1920, a great deal of research has been carried on by the Engineering Experiment Station at Iowa State College.

Cornstalks were selected as a raw material becuase they were abundant and low in price. Various workers have summarized the data on the cost of harvesting the stalks (10, 11). The figures vary from two dollars and forty cents to four dollars and ninety-five cents per ton. The total cost of the stalks, including purchasing price, harvesting, and transportation to the plant is approximately eight dollars per ton.

As early as 1920 Mudge (55) and others produced a coarse grade of board from a combination of cornstalk and corncobs. At a later date, Kozak (21) improved the board by incorporating fibers of such materials as flax and cotton wood.

In 1927 Schneider (42) produced a good grade of mechanical board. His work proved that the rod mill was a more efficient machine for producing cornstalk pulp than the beater. During the same year Seidel (43) produced a better board than Schneider, both in strength and appearance, by removing the pith. He also carried out very interesting experiments on the fireproofing of wall board.

Since the fall of 1927, nearly all of the work on cornstalk wall board has been done on a semi-commercial scale. The work was carried on by the Engineering Experiment Station and the United States Bureau of Standards. The complete set up consisted of a large steam jacketed cooker, a Hollander or beater, an Oliver filter and other types of board forming machines, a Dowingtown press, and a Coe chain drive dryer. As this process was continuous it was possible to secure a board of variable length. The width was twenty-four inches and was constant for all runs.

Various machines were tried in order to reach a conclusion as to the best methods. The Station designed a suitable board forming machine, with which it was possible to prepare a continous mat free from all laminations (49).

Richardson (36) completed some very interesting work on the sizing of wall board. He reported that wall board could be sized with materials other than rosin. At a later date (37) he presented a complete report on the semi-commercial plant. These facts were later used in designing commercial wall board plants.

B. Refrigeration Board

Successful thermal insulation involves a material consisting of innumerable air cells completely separated from each other. The insulating value of any material depends almost entirely upon the permanency of its cellular structure.

The early history of refrigeration shows that cork was the first product to be used in refrigeration. Cork is a natural product containing a great number of closely packed air cells separated from each other by thin walls of vegetable tissues (2). The cork of commercial use is the external part of the cork oak, a tree that flourishes only in the hot and semi-arid climate of the Spanish Peninsula and parts of northern Africa. The harvesting and marketing of cork are expensive (41, 46).

Numerous attempts have been made to transplant the cork oak to other parts of the globe, but all of these results have proven unsuccessful. Many other materials have been exploited for use as substitutes for corkwood in the thermal insulation industry. At the Fourth National French Refrigeration Congress (32) held in 1924 the necessity of finding a new material for insulating refrigeration apparatus was strongly emphasized in view of the rapid depletion of the virgin cork forests of the Mediterranean.

Of the fibrous vegetable and wood materials that are being used in the manufacture of insulating materials of low thermal conductivity wood pulp products are not a dependable source, due to the rapid disappearance of the nation's forest resources.

A good thermal insulator should be a poor conductor of heat. The ordinary measure of heat conductivity of a material in the United States is the amount of heat in British Thermal Units which will flow in one hour through a layer of the material one square foot in area when the temperature difference between the surfaces of the layer is one degree Fahrenheit per inch of thickness. Table 1, page 21, lists the insulating values of the various heat insulation on the market today (1).

Generally the lighter the material per unit total volume (1), the better is its insulating value per inch of thickness. Rigid fibrous insulating boards having considerable structural strength are somewhat poorer insulators than the looser and lighter materials. For insulation only, one must consider the question of thickness of the material applied. The material must be at least one-fourth of an inch thick in order to prevent the air currents from passing through. The maximum thickness depends on the quality of the insulation.

TABLE NO. 1.
PHYSICAL PROPERTIES OF COMMERCIAL INSULATION

MATERIAL	REMARKS	THERMAL CONDUCTIVITY		DENSITY	
		K x 10	k	D	d
AIR	If no heat is transferred by radiation or convection	6.0	4.2	0.0012	0.08
CALORAY	Fluffy mineral powder	7.6	5.3	0.064	4.0
KAPOK	Hollow vegetable fibers loosely packed	8.2	5.7	0.014	0.88
PURE WOOL		8.4	5.9	0.11	6.9
PURE WOOL		8.4	5.9	0.10	6.3
HAIR FELT	Fibers perpendicular to heat flow	8.5	5.9	0.27	17.0
PURE WOOL		9.0	6.3	0.08	5.0
SLAG WOOL	Loosely Packed	9.0	6.3	0.20	12.0
KEYSTONE HAIR	Hair felt and other fibers confined with building paper	9.3	6.5	0.30	19.0
MINERAL WOOL	Loosely Packed	9.3	6.5	0.20	12.0
CORKBOARD	No artificial binder; low density	9.3	6.5	0.11	6.9
MINERAL WOOL	Fibers perpendicular to heat flow	9.9	6.9	0.29	18.0
COTTON WOOL	Medium Packed	10.0	7.0	0.08	5.0
PURE WOOL	Very loose packing probably air circulation through material	10.1	7.0	0.04	2.5
INSULITE	Pressed Wood Pulp	10.2	7.1	0.19	12.0
MINERAL WOOL	Firmly Packed	10.2	7.1	0.34	21.0
LINOFELT	Vegetable fiber confined with paper Flexible and soft	10.3	7.2	0.18	11.3
GROUND CORK	Less than $\frac{1}{16}$ inch	10.2	7.1	0.15	9.4
CORKBOARD	No artificial binder	10.4	7.3	0.16	9.9
CORKBOARD	No artificial binder	10.6	7.4	0.18	11.3
SIL-O-CEL	Pulverized	10.6	7.4	0.17	10.6
REGRANULATED CORK	About $\frac{3}{16}$ inch	10.7	7.5	0.13	8.1
BALSA WOOD	Very light wood across grain	10.7	7.5	0.113	7.1
BALSA WOOD	Same sample with 13% waterproofing compounds.	11.9	8.3	0.128	8.0
COTTONSEED HULL FIBER	Loosely Packed	10.8	7.5	0.071	4.4

TABLE NO. 1 (continued)

PHYSICAL PROPERTIES OF COMMERCIAL INSULATION

MATERIAL	REMARKS	THERMAL CONDUCTIVITY		DENSITY	
		K x 10	k	D	d
CABOTS QUILT	Eelgrass enclosed in burlap	11.0	7.7	0.25	16.0
FLAXLINUM	Felted Vegetable Fibers	11.3	7.9	0.18	11.0
FIBROFELT	Felted Vegetable Fibers	11.3	7.9	0.18	11.0
ROCK CORK	Mineral Wool and binder	11.3	7.9	0.25	16.0
CEIBA WOOD	Across grain-untreated	11.3	7.9	0.113	7.1
BALSA WOOD	Across grain-untreated	11.9	8.3	0.118	7.4
BURRASH	Confined with cloth	11.6	8.1	0.14	8.8
CORKBOARD	With Bituminous binder	12.1	8.4	0.25	16.0
WOOD FELT	Flexible paper stock	12.5	8.7	0.33	21.0
LITHBOARD	Mineral Wool, vegetable fibers, and binder	13.1	9.1	0.20	12.5
BALSA WOOD	Medium Weight Wood	13.2	9.2	0.14	8.8
SAWDUST	Various	14.0	9.7	0.19	12.0
PLANER SHAVINGS	Various	14.0	10.0	0.14	8.8
WALL BOARD	Stiff Paste Board	17.0	12.0	0.69	43.0
AIR CELL ½ INCH	Corrugated asbestos enclosing air spaces	15.0	11.0	0.14	8.8
AIR CELL 1 INCH	Ditto	17.0	12.0	0.14	8.8
ASBESTOS PAPER	Built up of thin layers	17.0	12.0	0.50	31.0
ZENITHERM	Infusorial earth and asbestos	17.0	12.0	0.26	16.0
85% MAGNESIA	Magnesia and asbestos	17.5	12.0	0.31	19.0
INSULEX	Asbestos and plaster blocks, very porous	19.0	13.5	0.29	18.0
SIL-O-CEL	Infusorial earth, natural blocks	20.0	14.0	0.45	28.0
SIL-O-CEL	Ditto	21.4	15.0	0.50	31.0
BALSA WOOD	Heavy	20.0	14.0	0.33	20.0
FIRE FELT SHEET	Asbestos sheet coated with cement	21.0	14.0	0.42	26.0
FIRE FELT ROLL	Flexible Asbestos Sheet	22.0	15.0	0.68	43.0
CYPRESS	Across grain	23.0	16.0	0.46	29.0
FULLER'S EARTH		24.0	17.0	0.53	33.0
ASPHALT ROOFING	Felt saturated with asphalt	24.0	17.0	0.88	55.0

TABLE NO. 1 (Concluded)

PHYSICAL PROPERTIES OF COMMERCIAL INSULATION

MATERIAL	REMARKS	THERMAL CONDUCTIVITY		DENSITY	
		K x 10	k	D	d
WHITE PINE	Across grain	27.0	19.0	0.50	32.0
ASBESTOS MILL BOARD		29.0	20.0	0.97	61.0
MAHOGANY	Across grain	31.0	22.0	0.55	34.0
VIRGINIA PINE	Across grain	33.0	23.0	0.55	34.0
OAK	Across grain	35.0	24.0	0.61	38.0
MAPLE	Across grain	38.0	27.0	0.71	44.0
SOLE LEATHER		38.0	26.0	1.00	62.0
RUBBER	Soft Vulcanized	42.0	29.0	1.1	69.0
TEXTAN	Rubber Composition	40.0	28.0	1.3	81.0
WHITE CELLULOID		50.0	35.0	1.4	88.0
PARAFFIN	"Parawax" melting point 52° C.	55.0	38.0	0.89	56.0
GYPSUM PLASTER		80.0	56.0	0.74	46.0
ASBESTOS WOOD	Asbestos and Cement	93.0	65.0	1.97	123.0

K = Thermal Conductivity in Cal. $sec.^{-1} cm.^{-1} deg.^{-1}$

k = Thermal Conductivity in B.t.u. per day (24 hr.) per sq. ft. per deg. fahr. per in. thickness

$k = 69700\,K$

D = Density in grams per $cm.^3$

d = Density in lbs. per cu. ft.

$d = 62.5\,D$

Wunderlick (66), of the Flaxlinum Insulation Company, calculated the economical thickness for his product. He reported a value of one inch for the side walls and one and one-half for the ceiling.

Cover (8) computed the economical thickness for Armstrong Corkboard. He recommended a thickness of one and one-half to two inches for the side walls and two inches for the ceiling. Sanborn (67) estimated the cheapest installation to be one inch.

It is necessary to waterproof all insulation. There is none on the market today that will not absorb some water. If the air about the insulator is cooled below the dew-point, water appears on the surface of the insulation. The walls and ceiling construction are naturally cooler than the air in the room and therefore they will cool the air. Experience with refrigerating plants (18) shows that cork insulation used against brick walls will absorb moisture, thus partly nullifying the insulation properties. An asphaltic mastic finish about one-eighth inch thick is usually applied to refrigeration installations (23).

Additional properties of insulating materials are very necessary. A good insulator should be vermin proof, permanent in form, easy to handle, reasonable in cost and suitable for a plaster base.

C. Pressboard

As the name implies, pressboard is that type of board made by drying sheets of cellulosic materials under pressure. The outstanding characteristics of this board are high strength and density.

Many patents have been granted on various processes of producing laminated or built-up pressboard. The first patent was granted to Hansen in 1878. He produced a thick, hard board by saturating several paper boards with oil and subjecting the laminated boards to high pressure. Several small changes were made in producing this type of board during the next fifty years.

The outstanding patent issued on pressboard during 1924 was granted to Castner. He produced a good grade of compressed fiber board free from any binding materials.

Four years later Mason was granted three patents (56) (58)(59). One consisted of forming fiber into sheet form from hot water. This sheet was then pressed by rolls and dried. Another one was issued on the process of making a hard grainless fiber board. This was accomplished by making exploded wood fiber into a sheet and drying in a press under a pressure of two hundred to seven hundred pounds per square inch. The board was completely dried in the press with at least one side in contact with a wire mesh screen.

The last patent dealt with the process of forming integral fiber boards which were respectively very dense and porous.

The last patent issued on pressboard was granted to Sweeney in 1930 (60). This patent consisted of the following steps: first, reducing cornstalks or other similar materials to a pulp; second, forming the pulp into a mat; and, third, pressing the mat in a hydraulic press in the presence of heat.

To date there are only a few companies that have successfully manufactured pressboard. Among those who have produced a good board may be listed: Masonite, Vazcane, Celotex, and Pantosote. Only the first two have described their processes in detail. Within the last three years the Masonite Corporation (25) has grown from a small industry producing 40,000 feet of board to an industry producing 360,000 feet per day. The Vazcane process (47) was developed several year later than the Masonite process. Seidel, originally from the United States Bureau of Standards, has charge of this plant which is located at Havana, Cuba.

The first work done on pressboard at Iowa State College was completed in 1921 by Mudge (55), Mina (28), and others. They produced a hard, dense board from cornstalks and corncobs which had a clean, smooth surface. This surface was secured by using a nickel plate. Several years later

Kozak (21) completed some interesting work on this type of board.

During 1927 Reece and Hartford (35) carried out some research using a large hydraulic press. In the spring of 1929 these series of studies were started.

Most all of the early studies on pressboard at Iowa State College were made on mechanical pulp. Cornstalks were first passed through a shredder, then placed into a beater. The shredded stalks were diluted with enough water to permit the contents to circulate. The beater roll was lowered gradually in order to cause a slow hydration of the pulp. After some hours of beating, the pulp was formed into a mat by means of a large suction mold.

This mat was placed into a hydraulic press where the excess water was pressed out. The pressed mat was later dried in an oven for a variable length of time, then placed into the hydraulic press under a pressure of 1200 to 1500 pounds gauge pressure. The steam was turned on while the boards were being pressed. Some boards were made by cooking the cornstalks with chemicals, such as caustic soda and lime. Duplicate results were difficult because of many unstudied variables.

III

EXPERIMENTAL

A. Purpose of Study

The object of this thesis is to carry out such studies as will tend to further the production of synthetic lumber from cornstalks.

B. Method of Procedure

The studies carried out were divided into two parts, first, some factors affecting the production of insulation board, and second, the development of the commercial production of refrigeration board and pressboard.

Only those studies were made in the first part that would be of commercial importance. The samples of commercial insulation board were purchased from the local lumber yards of Ames.

The studies made on the second portion of the investigation were: first, the study of the feasibility of producing a refrigeration board from the cornstalk, such problems as method of separation, drying, insulating value, waterproofing, and fireproofing were studied; second, the study of determining the optimum conditions for producing pressboard.

Materials Used

The cornstalks used in the investigation were harvested from Story county farms two and three years ago. The various sizing materials were furnished through the courtesy of the following companies:

Paraffin emulsions from

Bennett Incorporated
161 Sidney Street
Cambridge, Mass.

Emulsified asphalt from

The Barber Asphalt Company
1600 Arch Street
Philadelphia, Pa.

Fireproofing material from

The United Fireproofing Company
Rutherford, N. J.

Halowax from

The Halowax Corporation
247 Park Avenue
New York City

Sodium Alginate from

Kelco Company
San Diego
California

Rosin from

Paper Makers' Chemical Corporation
North Milwaukee
Wisconsin

Alum from

Merrimac Chemical Co.
148 State Street
Boston, Mass.

Bakelite Varnish from

Bakelite Corporation
Bloomfield, N. J.

C. Results

1. Insulation board

a. Chemical and physical tests on commercial wall boards

(1). Chemical

(a). Rosin extraction. The object of this series of tests was to determine the per cent of size used in the commercial wall board (41). The rosin was determined by the following procedure: The sample was shredded and placed in an open weighing bottle located in a desiccator, for twelve hours. Five grams of the sample were placed into a Soxhlet extraction thimble and were extracted ten times with a forty-three per cent alcohol solution. This solution was prepared by mixing together one hundred cubic centimeters of one per cent acetic acid, five cubic centimeters of glacial acetic acid, and one hundred cubic centimeters of water. The extraction was stopped just before the thimble was full for the eleventh time in order to recover the alcohol. The recovered alcohol was transferred to an evaporating dish and evaporated, on a steam bath, to a concentration of a few cubic centimeters. This concentrated solution was then cooled and dissolved in twenty-five cubic centimeters of ether. This solution was transferred to a large separatory funnel and mixed with one hundred and fifty cubic centimeters of distilled water and a small amount of sodium chloride. The water was drawn off into a second funnel and washed with another twenty-five cubic centimeters of ether. The ether extracts were combined and washed with one hundred cubic centimeter portions of distilled water until the interface was sharp. If the rosin formed an emulsion, it was broken by the addition of salt. The washed ether was transferred to a tared dish, then evaporated to dryness on a steam bath, and dried at one hundred degrees Centigrade for exactly one hour. See Table No. 1_{I}, page 32.

The samples from NuWood and Insulite gave the highest per cent of rosin while Celotex and cooked Maizewood gave the least. The first two boards were made from wood--thus the high percentage of rosin. Probably the process of manufacture makes a great deal of difference for Masonite had a low percentage of rosin.

(b). Determination of per cent ash. The procedure followed for the determination of ash was as follows: Three grams of the representative sample were placed in tared platinum crucibles and placed into a cold electric muffle furnace. The furnace was then brought up to heat, 800 to 1000 degrees Centigrade. The samples were taken in all cases on the board as received. See Table No. I, page 32.

TABLE NO. 1_I

CHEMICAL AND PHYSICAL TESTS ON COMMERCIAL WALLBOARD

Sample	Density Lbs/cu.ft	Modulus Lbs/sq in.	Ash %	Ether Extraction %	H_2O Absorption	
					% Gain ½ hr	% Gain 24 hrs
Nuwood	16.25	386	1.972	3.189	14.3	124.6
Masonite	21.73	388	.27	2.72	13.7	46.4
[illegible]	11.04	204	4.655	2.[illegible]06	21.3	63.2
Maizewood [illegible]	17.02	322	7.996	2.02	17.5	64.8
Insulite	18.56	716	.519	3.99	15.4	47.6
Celotex	16.55	356	2.66	2.15	22.1	74.2

TABLE NO. $1A_I$

ANALYSIS OF THE ASH OF COMMERCIAL WALLBOARD

BOARD	% ASH	% BY WT OF BOARD AS REC'D.				% BY WT. OF ASH			
		SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3
A	1.972	0.719	0.772	.0279	0.744	36.94	39.1	1.415	37.7
B	0.2785	0.0985	0.1044	0.0234	0.0810	35.3	37.5	8.4	29.1
C	4.655	2.760	1.489	0.3065	1.183	59.3	31.9	6.59	25.4
D	7.996	6.05	1.600	0.612	0.983	75.8	20.01	7.66	12.38
E	0.519	0.0566	0.2731	0.0334	0.2397	10.80	52.6	6.43	46.17
F	2.663	1.724	0.651	0.2762	0.3748	65.6	24.4	10.38	14.08

A very low figure of 0.27 per cent of ash was secured for Masonite. Two runs were made on this sample and the results checked. The high per cent for Maizewood indicated the fact that a large amount of dirt still remained in the board. The mechanical pulp was washed the same amount as the cooked pulp. More dirt was removed from the uncooked pulp.

(c). Analysis of ash. Enough of the sample had to be ashed to secure a 0.5 gram sample of the ash. In some cases a large amount of board had to be ashed. The ash was dissolved by hydrochloric acid. The per cent silica, and combined aluminum and iron oxides were determined as directed in Foulkes' "Notes on Analytical Chemistry" (12). Each step was carried out in detail due to an enormous amount of precipitate present. In order to dissolve the R_2O_3 a fusion was made with $KHSO_4$. See Mahin's "Quantitative Analysis" (26). All of the residue which could be removed from the crucible was placed in hydrochloric acid solution with one cubic centimeter of stannous chloride. After digestion, the material which did not dissolve was filtered and the filter paper was ignited in the original crucible. Another fusion was made with the above material, then the fused material was dissolved and added to the acidified solution above. When the stannous chloride was added some of the solutions became reddish orange or brown indicating the presence of platinum which would interfere with the titration of iron.

The procedure followed was that given in Treadwell and Hall's "Analytical Chemistry" Vol. I (54). The solution was heated to boiling and hydrogen sulfide was passed into the solution. The precipitate, consisting of platinum sulfide and sulfur, was filtered off and the solution was boiled in order to remove excess hydrogen sulfide. The ferrous iron was oxidized to ferric by the addition of dilute $KMnO_4$, one per cent was used, then heated to boiling and reduced by stannous chloride. Mercuric chloride was added and the solution was titrated by using sodium dichromate with di-phenylamine as an inside indicator. The standardization and titration was carried out according to Mahin.

The following calculations were used for determining the per cent of ash, silica, R_2O_3, Al_2O_3, and Fe_2O_3 in wall board:

$$\% \text{ ash} = \frac{\text{Wt of ash}}{\text{Wt of sample}}(100)$$

$$\text{Wt of sample to use for analysis} = \frac{(0.5)(100)}{\%\ \text{ash}}$$

$$\%\ \text{Silica} = \frac{\text{Wt of silica}}{\text{Wt of sample}}(100)$$

$$\%\ R_2O_3 = \frac{\text{Wt of } R_2O_3}{\text{Wt of sample}}(100)$$

Standardization of $Na_2Cr_2O_7$

$$\text{Normality} = \frac{\text{Wt of } Fe(NH_4)_2(SO_4)_2\ 6H_2O}{(\text{cc of } Na_2Cr_2O_7)\ \frac{Fe(NH_4)_2(SO_4)_2\ 6H_2O}{(1)(1000)}}$$

$$\%\ Fe_2O_3 = \frac{(\text{cc } Na_2Cr_2O_7)(N_{Na_2Cr_2O_7})\ \frac{Fe_2O_3}{(2)(1000)}}{\text{Wt of sample}}(100)$$

Per cent Al_2O_3 by wt of board as received

$$\%\ Al_2O_3 = \%\ R_2O_3 - \%\ Fe_2O_3$$

Calculation from per cent of board to per cent of ash

$$\%\ \text{oxide of ash} = \frac{\%\ \text{of oxide on wt of board}}{\%\ \text{of ash of board}}$$

See Table No. Ia_I.

Very little silica was discovered in Masonite. A high per cent of silica was found in the cooked Maizewood board. This was probably due to an insufficient amount of washing during the preparation of the pulp. Less Al_2O_3 was found in the cooked Maizewood than in any of the boards.

(2). Physical

(a). Modulus of rupture. The modulus of rupture was determined on each board. Samples six inches long and three inches wide were used for this test. A three inch sample was sawed from the above speciman for moisture absorption. The sample was weighed and immersed in water for one-half hour, then removed, shaken once and allowed to drain for one minute. The speciman was then weighed and immersed for twenty-four hours. The same method of weighing was repeated. The density of the boards was determined by dividing the weight of an eight inch square sample by its volume. See Table No. I, page 32.

Insulite proved to be the strongest board. It also gave the lowest moisture absorption. NuWood proved to be the poorest board tested.

b. Expansion and Contraction of wall board

(1). Laboratory conditions. Four commercial boards, Celotex, Masonite, Insulite, and Maizewood were kept at 80°F and thirty per cent humidity for several weeks. The per cent moisture was determined both before and after the test. Small screws were inserted at the corners of the boards in order to furnish definite points for measuring. The length, width, thickness, weight, and humidity were recorded each day. See Tables No. 2_I to 5_I, pages 39 to 40 inclusive.

Table No. 2_I

EXPANSION OF CELOTEX

Date	Weight (gms.)	Length (inches)	Width (inches)	Thickness (inches)	Relative Humidity (per cent)
Mar. 11, '31	7921	78.31	43.97	0.541	42
12	7861	78.31	43.94	0.541	38
13	7921	78.34	43.94	0.538	40
14	7852	78.38	43.94	0.539	45
15	7873	78.34	43.94	0.537	42
16	7921	78.41	43.94	0.542	40
17	7875	78.38	43.94	0.600	22
18	7904	78.31	44.00	0.551	40
19	7843	78.31	43.94	0.560	30
20	7844	78.31	43.94	0.548	25
21	7846	78.38	43.94	0.535	30
22	7822	78.25	43.94	0.536	26
23	7796	78.31	43.94	0.550	28
24	7807	78.31	43.94	0.538	19
25	7801	78.25	43.94	0.550	13
26	7753	78.31	43.94	0.535	30
27	7805	78.31	43.94	0.550	38
28	7802	78.34	43.94	0.554	36
29	7839	78.34	43.94	0.553	38

Per Cent Moisture As Received - 6.35

Table No. 3_I

EXPANSION OF INSULITE

Date	Weight (gms.)	Length (inches)	Width (inches)	Thickness (inches)	Relative Humidity (per cent)
Mar. 11, '31	1872	43.87	13.75	0.608	42
12	1859	43.81	13.75	0.616	38
13	1855	43.81	13.75	0.612	40
14	1822	43.81	13.75	0.601	42
15	1837	43.81	13.75	0.611	45
16	1851	43.81	13.75	0.602	40
17	1853	43.81	13.75	0.600	22
18	1848	43.84	13.78	0.600	40
19	1878	43.84	13.75	0.602	30
20	1840	43.78	13.81	0.602	25
21	1832	43.78	13.75	0.596	30
22	1835	43.75	13.81	0.612	26
23	1865	43.81	13.75	0.587	28
24	1883	43.75	13.75	0.600	19
25	1810	43.81	13.75	0.599	13
26	1812	43.81	13.75	0.601	30
27	1804	43.81	13.75	0.602	38
28	1847	43.81	13.75	0.597	36
29	1853	43.81	13.75	0.601	38

Per Cent Moisture As Received - 6.51

Table No. 4_I

EXPANSION OF MAIZEWOOD

Date	Weight (gms.)	Length (inches)	Width (inches)	Thickness (inches)	Relative Humidity (per cent)
Mar. 11, '31	6963	62.13	45.84	0.586	42
12	6988	62.09	45.81	0.580	38
13	6993	62.13	45.81	0.581	40
14	6971	62.09	45.88	0.573	42
15	6982	62.09	45.91	0.580	45
16	6963	62.16	45.84	0.574	40
17	7021	62.13	45.88	0.592	22
18	6981	62.13	45.88	0.581	40
19	7029	62.16	45.91	0.596	30
20	7011	62.13	45.91	0.586	25
21	6991	62.13	45.81	0.572	30
22	7021	62.13	45.88	0.603	26
23	6931	62.13	45.88	0.578	28
24	6961	62.13	45.94	0.577	19
25	6957	62.13	45.94	0.577	13
26	6921	62.13	45.94	0.575	30
27	6929	62.13	45.88	0.580	38
28	6921	62.13	45.88	0.575	36
29	6913	62.13	45.88	0.572	38

Per Cent Moisture After 30 Days in Lab. - 4.83

TABLE NO. 5.
EXPANSION OF MASONITE

DATE	WEIGHT (GRAMS)	LENGTH (INCHES)	WIDTH (INCHES)	THICKNESS (INCHES)	RELATIVE HUMIDITY (PER CENT)
Mar. 11, 1931	10353	81.72	44.47	.570	42
12	10275	81.69	44.53	.571	38
13	10247	81.75	44.41	.564	40
14	10361	81.66	44.56	.562	42
15	10355	81.75	44.56	.569	45
16	10363	81.75	44.62	.570	40
17	10285	81.78	44.47	.585	22
18	10277	81.75	44.44	.550	40
19	10331	81.78	44.44	.569	30
20	10265	81.75	44.50	.567	25
21	10306	81.75	44.44	.564	30
22	10311	81.75	44.47	.596	26
23	10221	81.75	44.47	.562	28
24	10269	81.78	44.47	.564	19
25	10260	81.75	44.50	.563	13
26	10263	81.69	44.44	.566	30
27	10229	81.75	44.47	.566	38
28	10291	81.75	44.47	.564	36
29	10221	81.69	44.44	.564	38

Percent moisture as received, 4.92

Celotex varied in length five thirty-seconds of an inch and in width two thirty-seconds of an inch. Insulite varied in length three thirty-seconds and in width two thirty-seconds of an inch. Maizewood varied in length two thirty-seconds and in width four thirty-seconds of an inch. In every case the boards lost moisture by standing in the laboratory. The final moisture contents of the boards were: Celotex 5.16 per cent, Insulite 5.70 per cent, Maizewood 4.2 per cent, and Masonite 4.2 per cent.

(2). Effect at various humidities. Three commercial boards were used in this study: Celotex, Insulite, and both the unsanded and the sanded Maizewood. Twelve inch samples were used. Four small screws were placed at the corners of each board. The boards were dried two hours at 105° Centigrade and allowed to stand at room temperature for twenty minutes to permit cooling and to secure uniform initial measurements. A steel rule divided in one-hundredths of an inch was used to measure the length and width. The thickness was secured by means of a micrometer. The boards were then placed in an atmosphere of one hundred per cent humidity at 25° Centigrade. Readings were taken every twenty-four hours until constant. The boards were then placed in an atmosphere of seventy per cent humidity at a temperature of 21° Centigrade. Readings were taken every twenty-four hours until constant. See Tables No. 6_I and No. 7_I, pages 42 to 43 inclusive.

TABLE NO. 6$_I$

PER CENT EXPANSION* OF FOUR COMMERCIAL WALLBOARDS AT 100% REL. HUMIDITY, 25°C.

TIME FROM INITIAL MEASURE	SANDED MAIZEWOOD		MAIZEWOOD		CELOTEX		INSULITE	
	LENGTH	WIDTH	LENGTH	WIDTH	LENGTH	WIDTH	LENGTH	WIDTH
24 hrs.	0.50	0.51	0.63	0.38	0.38	0.25	0.63	0.51
48 hrs	0.12	0.12	0.00	0.13	0.00	0.12	0.00	0.00
72 hrs.	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL EXPANSION	0.74	0.63	0.63	0.51	0.38	0.37	0.63	0.51

*Length and Width

TABLE NO. 7$_I$

PER CENT EXPANSION* OF FOUR COMMERCIAL WALLBOARDS AT 70% REL. HUMIDITY, 25°C.

TIME FROM INITIAL MEASURE	SANDED MAIZEWOOD		MAIZEWOOD		CELOTEX		INSULITE	
	LENGTH	WIDTH	LENGTH	WIDTH	LENGTH	WIDTH	LENGTH	WIDTH
24 hrs.	0.50	0.25	0.50	0.25	0.12	0.36	0.37	0.24
48 hrs.		0.12	0.12	0.12		—	—	—
72 hrs.	—	—	—	—	—	—	—	—
TOTAL EXPANSION	0.50	0.37	0.62	0.37	0.12	0.36	0.37	0.24

*Length and Width

Celotex seemed to expand the least at both the seventy and one hundred per cent humidities. There seemed to be little difference in expansion for Maizewood and Insulite at one hundred per cent humidity but Maizewood expanded slightly more for the seventy per cent. Very little difference was noted for the expansion of the unsanded and the sanded Maizewood at the lower humidity.

(3). Drying to constant weight. Two finished Maizewood boards were dried to constant weight and then measured every five minutes for one hour. Then the boards were measured twice a day for two weeks. See Table No. 8_I, page 44 .

No change in length was noticed for the first hour. During the next twenty-four hours the board expanded to its original length and width before drying. No change was noticed for the next fourteen days.

(4). After immersion in water. Two standard Maizewood lath were measured carefully, then they were immersed in water for twenty-four hours. They were removed and measured. Five days later the lath were again measured. Then they were immersed another twenty-four hours. Two more readings were taken, one directly after removing the lath from the water, and the other seven days later. See Table No. 9_I, page 45.

The lath expanded about the same amount after each im-

TABLE NO. 8_I

EXPANSION OF FINISHED MAIZEWOOD

DATE	BOARD NO. I			% HUMIDITY	BOARD NO. II		
	LENGTH	WIDTH	THICK.		LENGTH	WIDTH	THICK.
Feb. 25, Original	21.00	21.13	.558	30	21.00	21.44	.566
" 25, 5 P.M.	21.06	21.13	.558	30	21.00	21.44	.572
26, 9 A.M.	21.13	21.19	.559	38	21.06	21.50	.572
26, 5 P.M.	21.13	21.19	.559	30	21.06	21.50	.572
27, 9 A.M.	21.13	21.19	.557	32	21.06	21.50	.570
27, 5 P.M.	21.13	21.19	.557	33	21.06	21.50	.572
28, 9 A.M.	21.13	21.19	.553	39	21.06	21.50	.578
Mar. 1, 5 P.M.	21.13	21.19	.560	58	21.06	21.50	.574
2, 9 A.M.	21.13	21.19	.553	41	21.06	21.50	.572
2, 5 P.M.	21.13	21.19	.548	40	21.06	21.50	.562
3, 9 A.M.	21.13	21.19	.553	33	21.06	21.50	.513
3, 5 P.M.	21.13	21.19	.554	32	21.06	21.50	.567
4, 9 A.M.	21.13	21.19	.552	34	21.06	21.50	.566
4, 5 P.M.	21.13	21.19	.555	31	21.06	21.50	.567
5, 9 A.M.	21.13	21.19	.555	40	21.06	21.50	.568
5, 5 P.M.	21.13	21.19	.553	37	21.06	21.50	.567
6, 9 A.M.	21.13	21.19	.552	35	21.06	21.50	.565
6, 5 P.M.	21.13	21.19	.554	28	21.06	21.50	.566
7, 9 A.M.	21.13	21.19	.555	30	21.06	21.50	.566
7, 5 P.M.	21.13	21.19	.556	33	21.06	21.50	.567
8, 9 A.M.	21.13	21.19	.557	40	21.06	21.50	.570
8, 5 P.M.	21.13	21.19	.558	38	21.06	21.50	.569
9, 9 A.M.	21.13	21.19	.558	37	21.06	21.50	.568
9, 5 P.M.	21.13	21.19	.556	30	21.06	21.50	.568
10, 9 A.M.	21.13	21.19	.555	32	21.06	21.50	.567
10, 5 P.M.	21.13	21.19	.555	30	21.06	21.50	.568
11, 9 A.M.	21.13	21.19	.555	33	21.06	21.50	.566

Note: No change for five minute intervals for 1st hour.

TABLE NO. 9,
EXPANSION TESTS ON MAIZEWOOD LATH

NO. 1	LENGTH	WIDTH	THICKNESS			
			TOP	BOTTOM	RIGHT	LEFT
Original	48.00	18.00	0.468	0.474	0.485	0.482
Measured after 24 hrs. immersion	48.38	18.13	0.500	0.532	0.500	0.532
Measured 5 days after immersion	47.94	18.06	0.495	0.484	0.486	0.499
Measured after 2nd 24 hr. immersion	48.38	18.19	0.500	0.517	0.489	0.524
Measured 7 days after 2nd immersion	47.69	17.81	0.492	0.493	0.480	– –

Original	48.00	18.00	0.482	0.475	0.497	0.470
Measured after 24 hrs. immersion	48.38	18.13	0.520	0.517	0.523	0.506
Measured 5 days after immersion	47.81	17.94	0.498	0.487	0.509	0.484
Measured after 2nd 24 hr. immersion	48.31	18.19	0.524	0.513	0.534	0.499
Measured 7 days after 2nd immersion	47.75	17.88	0.498	0.486	0.515	0.468

mersion. In all cases they contracted to a figure lower than the original length or width. The lath did not expand in length on being nailed to ordinary studding. Some expansion in width was noted.

(5). Effect of varying percentages of moisture. The purpose of this series of studies was to determine the effect moisture plays on expansion and contraction. A mechanical board was made containing twenty-two per cent newsprint. This board was sized with three per cent rosin and five per cent alum. The wet mat was run into the dryer and dried for two hours. The mat still containing over twenty per cent moisture was sawed up into three foot samples. Each board was marked in order to measure its length and width. The length, width, thickness and weight were taken on each board. All the boards were placed in the dryer and one board was removed at the end of each pass through the dryer. One complete pass required seven minutes. At the end of each pass each board was weighed and measured. Eleven boards were run in this series. The next series of thirteen boards were run exactly the same as above only the boards were dried two and one-half hours. The last series of thirteen boards was run exactly the same except the boards were dried three hours before weighing and measuring.

The above thirty-seven boards were weighed and measured twice a day for the first week. Then once a day for the next two weeks.

The boards were placed in the laboratory for a few days, then placed in the basement in order to vary the humidity. The humidity was determined by means of a sling psychrometer. See special report (34) for results of the test.

Boards containing from five to six per cent moisture seemed to expand less than boards containing higher per cents. The humidity caused a great deal of change in length. The boards should be held at a humidity for some length of time in order to reach equilibrium. Some error in reading was made in measuring due to experimental error since the boards were measured by different people. The curves plotted for this series show the relation of change in length with per cent moisture.

The modulus of rupture, density and moisture absorption were determined by the usual procedure for each of the thirty-seven boards. See Table No. 10_I, page 48 .

No decided effect was noted from the varying percentages of moisture on strength, density, and moisture absorption.

(5) Effect of newsprint on expansion. Two lath were weighed and measured. One, called "A", made of over fifty per cent newsprint, and the other, "B", standard lath made of twenty-four per cent newsprint. These lath were first placed at laboratory conditions. They were weighed and measured for four days, then heated to constant weight

TABLE NO. 10

PHYSICAL TESTS ON SPECIAL WALLBOARD RUN

BOARD NO.	% MOISTURE	DENSITY LBS./CU.FT.	MODULUS LBS./SQ.IN.	MOISTURE ABSORPTION		TIME OF DRYING (MINUTES)
				½ HR.	24 HRS	
1	34.0	13.1	287	19.3	85.0	120
2	31.4	13.7	271	25.5	80.0	127
3	34.6	13.2	278	21.6	84.6	137
4	36.6	12.4	283	29.1	92.4	141
5	35.6	14.5	230	12.3	690	148
6	38.2	12.4	233	22.0	91.8	155
7	40.0	11.4	190	20.8	84.3	162
8	38.4	12.4	201	22.0	140.0	169
9	36.4	13.4	254	24.2	134.0	176
10	31.2	12.9	320	20.7	140.0	183
11	15.4	12.3	270	22.0	151.0	190
12	9.7	12.3	240	26.4	176.6	150
13	19.8	14.0	280	19.1	157.4	157
14	12.4	13.2	270	16.9	145.1	164
15	19.2	13.5	260	19.6	144.0	171
16	20.8	13.9	255	19.6	153.5	178
17	13.6	12.4	240	23.8	148.8	185
18	25.0	12.6	220	22.0	178.1	192
19	19.4	12.9	260	27.0	182.7	199
20	11.9	11.7	258	22.4	96.0	206
21	0.1	12.1	233	27.3	190.0	213
22	0.0	13.4	256	29.3	171.0	220
23	0.2	13.0	277	23.1	98.1	227
24	1.0	13.6	291	23.6	153.0	234
25	0.9	14.7	251	21.7	115.0	180
26	2.6	14.6	235	18.1	102.0	187
27	6.1	15.4	280	19.6	113.0	194
28	11.7	13.6	275	16.6	94.0	201
29	10.3	14.7	237	20.4	119.0	208
30	11.1	13.6	260	17.4	123.0	215
31	10.1	14.5	265	16.9	114.0	222
32	11.3	13.9	265	17.8	136.3	229
33	9.4	15.7	254	23.2	139.0	236
34	9.0	14.2	269	21.8	136.0	243
35	2.1	13.7	266	20.1	122.0	250
36	2.3	14.0	285	17.2	124.0	257
37	0.0	14.[illegible]	285	17.0	137.1	264

and weighed and measured again. After measuring they were again placed at laboratory conditions for four days. The lath were then removed to the basement for four days and later placed on the roof for four days. Each day the humidity was recorded as well as the weight and measurements. See Table No. 11_I, page 50.

Little or no difference was noted in the action of the two lath. A change in humidity did cause the boards to expand and contract. These changes were recorded as well as the weight and measurements. See Table No. 11_I, page 50.

(7). Effect of change in temperature on expansion and contraction at constant humidity. Samples of Celotex, Masonite, Insulite, and Maizewood were marked carefully at the corners with screws. The boards were heated to constant weight and measured accurately to the nearest hundredth of an inch. The boards were then placed at humidities of ten, twenty, forty, sixty, eighty, and one hundred. At each humidity readings were taken at various temperatures. The boards were held at each temperature twenty-four hours before measuring. See Tables No. 12_I to 16_I inclusive.

Temperature had little or no effect on expansion at the various humidities. The boards did expand at a higher humidity but the expansion at the various temperatures for each humidity was constant.

TABLE NO 11

EXPANSION STUDIES ON STANDARD LATH

DATE	LENGTH		WIDTH		THICKNESS		WEIGHT		% HUMIDITY	REMARKS
	a	t	a	b	a	b	a	b		
	40	40.19	16	15.72	.556	.498	2013	1641	40	Board placed in laboratory measured every 24 hrs
	40	40.19	16	15.72	.553	.500	1998	1619	35	
	40	40.19	16	15.72	.554	.499	2002	1622	35	
	40	40.19	16	15.72	.553	.500	2000	1621	35	
	39.94	40.03	15.97	15.66	.547	.495	1885	1503	—	Board dried to constant wt.
	40	40.19	16	15.69	.546	.488	2015	1610	35	Board placed in lab., measured every 24 hrs.
	40	40.31	16	15.72	.547	.493	2007	1622	28	
	40.03	40.31	15.97	15.72	.549	.495	2013	1640	32	
	40	40.31	16	15.72	.544	.495	1993	1600	38	
	40.05	40.50	16	15.72	.551	.495	2011	1635	55	Board placed in basement; measured every 24 hrs.
	40.06	40.19	16	15.72	.550	.491	2029	1645	50	
	40.03	40.19	16	15.72	.550	.492	2085	1663	45	
	40	40.17	16	15.22	.543	.494	2037	1629	45	
	39.97	40.09	16	15.42	.554	.490	2070	1585	15	Board placed on roof; measured every 24 hrs.
	40	40.19	16	15.72	.545	.485	2020	1655	55	
	40.03	40.22	16	15.72	.540	.496	2215	1634	49	
	40	40.19	16	15.72	.546	.487	2210	1652	50	

Table No. 12_I

EFFECT OF TEMPERATURE ON EXPANSION OF COMMERCIAL WALL BOARDS

AT 20 PER CENT RELATIVE HUMIDITY

	Temp. °C	Board Number A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
% Increase	22	0.30	0.35	0.13	0.08	0.00	0.03	0.13	0.13
in	23	0.30	0.40	0.23	0.18	0.02	0.08	0.08	0.18
Length	38*	0.30	0.30	0.35	0.18	0.03	0.02	0.08	0.13
% Increase	22	0.15	0.20	0.15	0.10	0.10	0.00	0.00	0.00
in	23	0.25	0.10	0.15	0.20	0.10	0.00	0.02	0.10
Width	38*	0.25	0.15	0.15	0.20	0.10	0.00	0.12	0.10
% Increase	22	0.35	0.18	0.00	0.00	0.39	0.20	0.27	0.00
in	23	0.00	0.00	0.21	0.00	0.39	0.00	0.00	0.37
Thickness	38*	0.43	0.36	0.00	0.00	0.97	0.30	0.23	0.18
% Increase	22	2.38	2.70	3.09	2.95	1.72	1.23	0.52	1.33
in	23	2.10	2.87	2.54	3.31	1.43	1.85	1.72	1.66
Weight	38*	1.87	2.79	2.00	2.35	2.29	1.70	0.00	1.22

*Results are average of two runs

Table No. 13_I

EFFECT OF TEMPERATURE ON EXPANSION OF COMMERCIAL WALL BOARDS

AT 40 PER CENT RELATIVE HUMIDITY

	Temp. °C	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
		Board Number							
% Increase	26	0.38	0.35	0.23	0.12	0.02	0.03	0.08	0.13
in	27.5	0.30	0.30	0.23	0.08	0.01	0.03	0.00	0.08
Length	35	0.45	0.50	0.18	0.23	0.02	0.13	0.18	0.23
	39	0.58	0.40	0.18	0.23	0.02	0.08	0.13	0.18
	41	0.53	0.40	0.18	0.23	0.02	0.13	0.13	0.18
% Increase	26	0.25	0.40	0.15	0.20	0.20	0.10	0.22	0.00
in	27.5	0.25	0.10	0.05	0.20	0.10	0.10	0.02	0.10
Width	35	0.35	0.30	0.25	0.30	0.20	0.10	0.12	0.10
	39	0.25	0.30	0.15	0.30	0.10	0.00	0.12	0.00
	41	0.25	0.30	0.15	0.30	0.10	0.00	0.12	0.00
% Increase	26	1.56	0.54	0.42	0.21	1.75	0.20	0.27	0.56
in	27.5	1.05	0.36	0.21	0.21	0.97	0.40	0.19	0.19
Thickness	35	1.90	0.11	0.89	0.62	1.75	0.40	0.56	0.19
	39	2.24	0.13	0.63	0.17	2.40	0.80	0.74	0.37
	41	1.90	0.91	0.42	1.24	1.94	0.60	0.74	0.19
% Increase	26	3.57	4.05	4.90	4.80	3.14	2.46	2.76	3.32
in	27.5	3.06	3.52	3.09	4.23	2.14	2.46	1.89	2.06
Weight	35	3.92	5.24	6.18	4.60	4.28	3.38	3.80	3.32
	39	3.40	5.24	5.82	4.05	3.14	2.78	3.45	3.11
	41	3.40	5.06	5.64	4.23	3.14	2.92	3.28	3.16

Table No. 14_I

EFFECT OF TEMPERATURE ON EXPANSION OF COMMERCIAL WALL BOARDS

AT 60 PER CENT RELATIVE HUMIDITY

	Temp. °C	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
		Board Number							
% Increase	25.5	0.63	0.65	0.28	0.28	0.20	0.28	0.23	0.33
in	31.0	0.63	0.65	0.28	0.28	0.20	0.28	0.23	0.33
Length	41.0	0.63	0.65	0.28	0.28	0.20	0.28	0.23	0.33
% Increase	25.5	0.55	0.40	0.25	0.30	0.30	0.10	0.22	0.10
in	31.0	0.55	0.40	0.25	0.30	0.30	0.10	0.22	0.10
Width	41.0	0.55	0.40	0.25	0.30	0.30	0.10	0.22	0.10
% Increase	25.5	0.21	0.18	0.15	0.10	0.23	0.14	0.15	0.09
in	31.0	0.25	0.18	0.13	0.17	0.23	0.14	0.15	0.11
Thickness	41.0	0.23	0.36	0.13	0.15	0.23	0.09	0.15	0.17
% Increase	25.5	6.63	8.60	7.63	7.55	6.00	4.76	6.20	6.81
in	31.0	6.63	8.45	8.00	7.91	5.55	4.76	4.83	6.81
Weight	41.0	6.46	6.42	7.63	8.29	4.13	4.76	4.47	5.98

Table No. 15_I

EFFECT OF TEMPERATURE ON EXPANSION OF COMMERCIAL WALL BOARDS

AT 80 PER CENT RELATIVE HUMIDITY

	Temp. °C	Board Number A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
% Increase	24.5	0.63	0.65	0.28	0.31	0.20	0.28	0.23	0.38
in	29.0	0.63	0.65	0.28	0.33	0.20	0.28	0.28	0.38
Length	33.0	0.63	0.65	0.28	0.33	0.20	0.28	0.28	0.38
	40.0	0.63	0.65	0.28	0.33	0.20	0.28	0.28	0.33
% Increase	24.5	0.55	0.51	0.45	0.40	0.30	0.20	0.22	0.20
in	29.0	0.55	0.51	0.45	0.40	0.30	0.20	0.22	0.20
Width	33.0	0.55	0.51	0.45	0.40	0.30	0.20	0.22	0.20
	40.0	0.60	0.51	0.45	0.40	0.30	0.20	0.22	0.20
% Increase	24.5	0.26	0.55	0.21	0.19	0.25	0.20	0.18	0.15
in	29.0	0.26	0.11	0.21	0.23	0.25	0.16	0.20	0.19
Thickness	33.0	0.28	0.11	0.21	0.23	0.27	0.16	0.18	0.19
	40.0	0.26	0.13	0.17	0.25	0.25	0.18	0.17	0.17
% Increase	24.5	6.46	8.45	8.20	9.40	5.27	5.18	5.76	6.65
in	29.0	6.63	9.80	9.10	9.92	5.27	5.70	7.60	6.81
Weight	33.0	7.32	9.80	9.10	9.92	5.27	6.15	6.90	7.48
	40.0	7.32	9.45	8.74	9.57	5.12	6.77	6.55	7.15

Table No. 16_I

EFFECT OF TEMPERATURE ON EXPANSION OF COMMERCIAL WALL BOARDS

AT 100 PER CENT RELATIVE HUMIDITY

	Temp. °C	Board Number							
		A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2
% Increase	22.0	0.70	0.71	0.39	0.36	0.25	0.30	0.28	0.38
in	29.2	0.74	0.74	0.39	0.38	0.25	0.33	0.28	0.38
Length	37.0	0.73	0.76	0.39	0.38	0.25	0.33	0.28	0.38
	40.0	0.73	0.76	0.39	0.38	0.25	0.33	0.33	0.38
% Increase	22.0	0.60	0.56	0.45	0.45	0.35	0.20	0.22	0.30
in	29.2	0.65	0.61	0.45	0.45	0.35	0.25	0.27	0.30
Width	37.0	0.65	0.61	0.45	0.45	0.35	0.30	0.27	0.30
	40.0	0.65	0.61	0.45	0.45	0.35	0.30	0.27	0130
% Increase	22.0	0.32	0.13	0.23	0.29	0.29	0.23	0.18	0.23
in	29.2	0.34	0.18	0.23	0.33	0.29	0.24	0.22	0.19
Thickness	37.0	0.34	0.19	0.23	0.35	0.29	0.26	0.22	0.19
	40.0	0.34	0.18	0.23	0.37	0.31	0.28	0.22	0.17
% Increase	22.0	8.85	10.1	10.4	10.3	6.42	8.00	7.75	9.80
in	29.2	9.35	10.8	10.5	10.5	6.98	8.00	6.60	10.6
Weight	37.0	9.35	11.2	10.4	10.5	6.85	8.00	7.92	10.6
	40.0	10.01	11.5	10.2	10.5	7.26	7.85	7.75	10.5

c. Fireproofing of wall board

(1). Laboratory studies. Cornstalks were cooked three hours, rod milled, and claflined five minutes. The mat was formed on the forming machine, then lapped and placed in the moisture proof box.

One pound of dry fiber was then placed in the beater with twenty-eight pounds of water. The contents were mixed for five minutes then various per cents of sodium silicate were added to the pulp. The mixing was continued for ten minutes. The pulp was formed into a mat and pressed slightly in a letter press. None of the boards were fireproofed.

The above series of studies were repeated using cornstalk cook liquor, asbestos, and several ammonium salts. No boards were secured that were fireproofed.

The next studies were made by dipping finished boards in the following solutions:

Na_2SiO_3	50% concentration
Na_2SiO_3	10% "
NH_4F	10% "
$(NH_4)_2HPO_4$	10% "
$Na_2B_4O_7$	10% "
$(NH_4)_2SO_4$	10% "
NH_4Cl	10% "
$FeSO_4$	10% "

The first four solutions gave fair fireproofing while the last four gave no fireproofing whatsoever. The sodium silicate increased the density of the board. The $(NH_4)_2HPO_4$ seemed to give the best results with the least amount of injury to the physical properties of the board.

Thomas (53) recommended various concentrations of potassium salts as possible fireproofing compounds.

Therefore a series of studies was made using cooked pulp. One pound of bone dry fiber and twenty-eight pounds of water were added to the one pound beater and the contents were circulated for five minutes. Various concentrations of potassium salts were added and the contents were again circulated for ten minutes. The mat was formed in the small suction box then pressed to a definite thickness. The boards were dried for four hours at one hundred and thirty degrees Centigrade. See Table No. 17_I, page 58.

None of the boards were fireproofed one hundred per cent. In every case except one, the boards were treated so that they did not blaze like the blank. The potassium acid sulphate seemed to decrease the moisture absorption as well as increase the strength. Potassium hydroxide injured the board very much. Potassium permanganate seemed to injure the appearance of the board.

Table No. 17_I

EFFECT OF POTASSIUM SALTS ON WALL BOARD

No.	Modulus	Density	Moisture Absorption %½ hr.	Moisture Absorption %24 hr.	Chemical used		Results
1	526.0	22.0	22.0	100.0	$KHSO_4$	7%	glowed at end of 3 sec
2	426.5	20.9	24.5	123.0	KNO_3	11%	"
3	508.0	19.1	24.5	88.8	K_2SO_4	10%	"
4	482.0	20.5	24.5	118.2	$KClO_4$	3%	"
5	454.0	18.9	45.4	179.0	$KMnO_4$	5%	"
6	489.0	20.5	294.5	327.5	No size (blank)		blazed at end of 3 sec
7	419.5	19.8	26.3	146.0	Sized (blank)		"
8	393.0	18.8	23.7	143.0	$KClO_3$	6.5%	glowed at end of 3 sec
9	433.0	20.6	34.4	115.0	KI	10%	"
10	515.5	19.6	55.9	204.5	$K_2C)O_3$	10%	"
11	538.0	17.5	23.6	107.1	KBr	10%	"
12	414.2	20.7	19.1	80.4	$K_2S_2O_8$	5%	"
13	388.0	20.1	22.8	113.6	KNO_2	7.7%	"
14	501.0	20.8	92.7	234.7	KOH	10%	"
15	365.0	17.1	28.0	145.0	$K_2Cr_2O_7$	6%	glowed at end of 3 sec

(2). Semi-commercial studies. The purpose of these studies was to determine the following facts: first, can wall board be fireproofed, second, does the compound injure the physical properties of the board, and third, is it economical.

The regular semi-commercial set up was used. Most of the runs were made on mechanical pulp containing sixteen per cent newsprint. The pulp was sized with an emulsified asphalt called "Stanolite" made by the Flinkote Company of Rutherford, New Jersey. The fireproofing compound consisted of various salts.

The refined pulp was placed in the mixing tanks and enough water was entered to give a two per cent consistency. Enough fireproofing compound was added until the Baume' reading was 12.5°. The pH was adjusted to 5.2 by means of a special solution put out by the fireproofing company. Eight per cent Stanolite fifty per cent, was added and the contents were mixed five minutes. The white waters* were saved and more fireproofing compound was added from time to time to secure the desired Baume'. Several runs were made at various degrees Baume'. See Table No. 18_I, page 60.

All of the boards were fireproofed one hundred per cent but the moisture absorption of the boards was very high. The

*Water removed from the wet pulp during formation of mat.

TABLE No. 17 I

WATERPROOFING OF WALLBOARD

NO.	PREPARATION OF PULP	STR. (M.R.)	WT.	% H_2O ABSORP.		SIZING MATERIAL	pH	BAUMÉ	REMARKS
				½ HR.	24 HRS.				
1	Mech. 16% News 39# 250 gal. H_2O 450# F.P., 3# of 50% Stanolite	240	715	77	195	Stanolite	5.2	12.5	Pulp too slow, crushed. Consistency-2%
2	39" Cooked P. 100 gal. H_2O 150 gal. white w., 60# F.P., 3" 50% Stanolite	400	872	145	252	Stanolite	5.2	9.0	Good formation Consistency-2%
[illegible]	Mech. 39#, 14.7% News. 250 gal. white w. 225# F.P., 4# 50% Stanolite	241	[illegible]	215	315	Stanolite	5.3	11.5	Pulp too free Poor formation Consistency -2%
3.	50 gal. of water added to above	231	710	72	230	Stanolite	5.3	9.0	Good formation Consistency-1.5%
4	39" Mech., 14% News, 250 gal. white w., 75# F.P., pH controlled with tartaric acid; 2% rosin	300	710	290	319	2% Rosin	5.1	9.0	Good formation Consistency-2%
5	27" Mech., 14% News, 200 gal. white W., 75# F.P., 2.2# 50% Stanolite	248	650	350	398	Stanolite	5.4	7.9	Good formation Consistency-2%

strength and density were affected very slightly. The cost would probably be too high.

d. Studies on mold action

Some complaint has been made that Maizewood would mold rapidly when placed in a moist atmosphere. Therefore samples of Masonite, Celotex, Insulite, and both the light weight and heavier weight Maizewood were placed over water in a desiccator at twenty-eight degrees Centigrade.

No signs of molding were noticed for the first five weeks. Several days later small spores of mold were noticed on the Maizewood samples. One day later the Celotex sample showed signs of molding. The samples of Insulite and Masonite showed signs of molding one week after Maizewood.

All samples were slightly covered with mold at the end of ten weeks.

The samples in the above tests were placed in an anaerobic condition. Additional samples were placed in an aerobic condition. To obtain this condition the specimens were placed in one liter beakers. They were again placed over water and the beaker was covered with a watch glass.

At the end of ten weeks the samples showed no signs of molding but a musty odor appeared.

(1). Chemicals added to the pulp. A very light mechanical board was made for these tests. One bale of cornstalks was rod milled rapidly, steamed two hours at one hundred and thirty-five degrees Fahrenheit, and claflined lightly for five minutes. The pulp was formed on the forming machine and then lapped.

Enough of this pulp was weighed out to give one pound of dry fiber. Twenty-eight pounds of water were added along with various per cents of zinc chloride, copper sulphate, and mercuric chloride. The contents were beaten for five minutes, then formed into a mat and dried. The following per cents of these chemicals were used:

Run No.	Chemical used	Density lbs per cubic foot
1	.05% $CuSO_4$	7.37
2	.10% "	7.10
3	.15% "	7.75
4	.20% "	7.38
5	.05% $ZnCl_2$	6.38
6	.10% "	6.72
7	.15% "	6.99
8	.20% "	6.94
9	.05% $HgCl_2$	8.65
10	.10% "	9.02
11	.15% "	7.42
12	.20% "	6.10

The above boards were placed in beakers as described previously. No signs of molding were noticed at the end of ten weeks. The samples were free from a musty odor.

Another series of boards was prepared in like manner, only they were pressed harder. The density of these boards averaged thirteen pounds per cubic foot.

This last series of boards were placed in a desiccator as was described in the first study. Mold appeared at the end of ten weeks.

(2). Chemicals sprayed on boards. Samples of Maizewood were either sprayed or dipped into various solutions in order to test their resistance to molding.

Some of the solutions used were:

1. Saturated copper sulphate.
2. Saturated zinc chloride.
3. Saturated mercuric chloride.
4. 1% sulphuric acid.
5. 1% sodium hydroxide.
6. Barber's emulsified asphalt.
7. Stanolite (an emulsified asphalt).
8. Barrett's prepared resin.
9. Bennett's prepared emulsion (edges only).
10. Bennett's prepared emulsion (entire sample).

The above samples were placed in beakers as before. Samples number five and nine showed signs of molding four weeks later. The other samples showed no signs at the end of ten weeks.

2. Refrigeration board

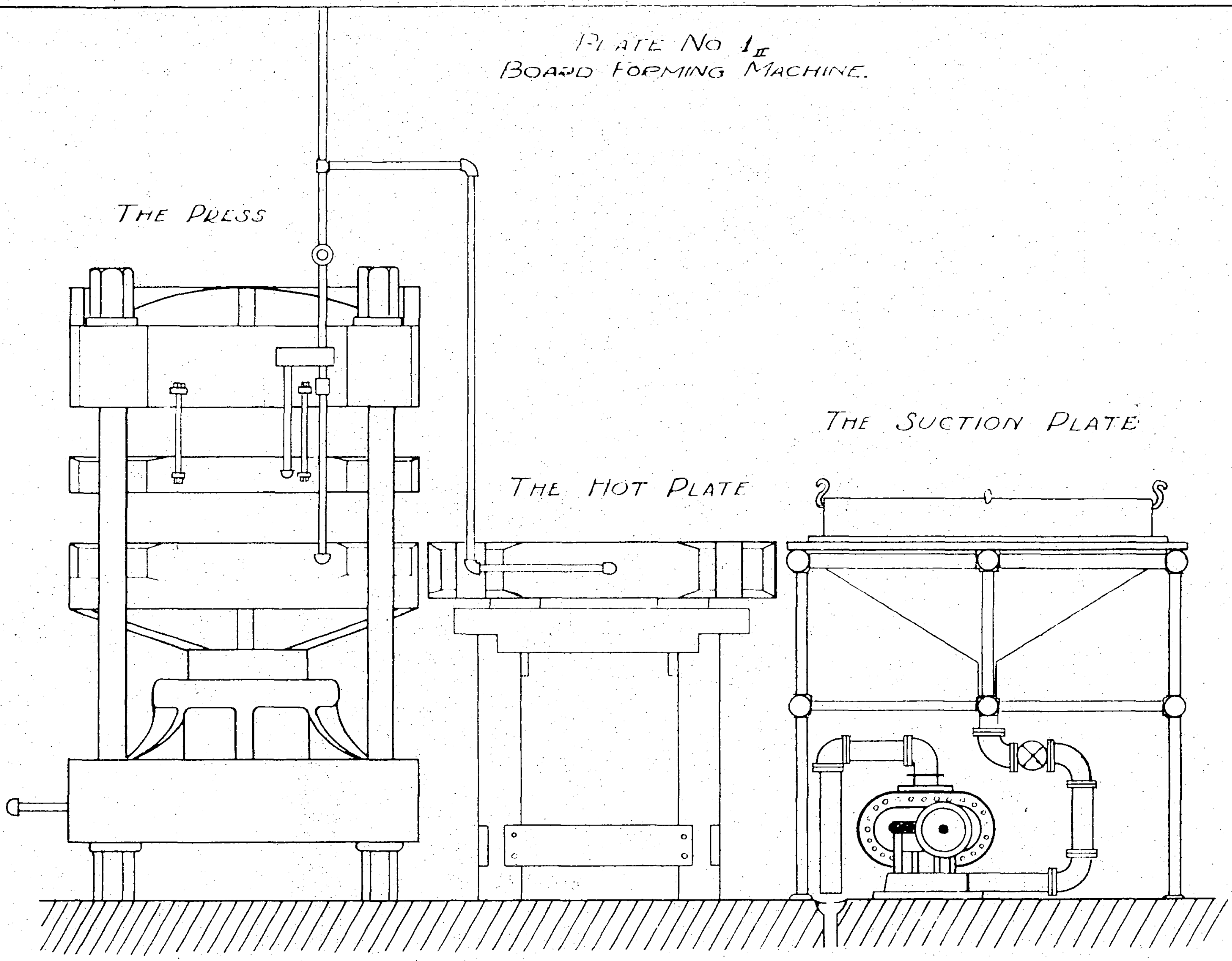
a. Preparation

Two types of refrigeration board were produced from cornstalks. The first was made by using the entire cornstalk, while the other was produced from the pith of this plant.

(1). Board from the whole stalk. The refrigeration board made from the whole stalks was produced by the following operations: shredding, passing the stalks through a rod mill, forming the pulp into a mat, and drying the mat. The first two operations should require no explanation as they have been explained in previous work.

The third operation was accomplished by the use of a forming machine as shown by Plate 1_{II}, page 65. It consisted of two sections, a flat perforated top about forty inches square and fitted with an inverted pyramidal drain converging to a two inch pipe leading to a vacuum pump located beneath the board forming table, and the upper container or deckel box which served to hold the water suspension of pulp until the latter was formed into a mat upon a screen resting between the two sections. The pulp, prepared in the rod mill or beater, was deposited in the upper container until the desired thickness was reached, the suction was applied and the deckel box was removed when the mat was sufficiently dry to hold its shape. The mat was then placed in a hydraulic press and com-

PLATE NO 1$_{II}$
BOARD FORMING MACHINE.



pletely dried by means of steam. No pressure was applied other than that necessary to give a surface to the board.

A series of runs was made in order to determine the best methods of producing this type of refrigeration board. The stalks were prepared in various ways. Some were cooked with water, others with caustic soda, while the rest were made from mechanical pulp. See Table no. 1_{II}, page 67.

The lightest boards in this series were made from either mechanical pulp or pulp that was given a short water cook. Fermentation seemed to add to the strength without greatly affecting the density. Boards prepared by cooking the pulp with caustic seemed to be unsatisfactory. The lowest density secured was five and two-tenths pounds per cubic foot. This figure was much lower than that for commercial corkboard.

Cornstalks were separated into their respective physical parts such as, leaves and husks, nodes, pith, and outer fibers. Boards were made from each of the above parts. The nodes produced very unsatisfactory boards. Caustic soda did not seem to break the nodes down sufficiently. The boards secured from the leaves and husks were very dense and dark colored due to the dirt which had been ground into them. The outer fibers produced very strong boards which were rather light in color. The pith produced a board which was very satisfactory, for it was very light and porous.

TABLE NO. 1_{II}

REFRIGERATION BOARDS FROM THE WHOLE CORNSTALK

NO.	PROCESS	THICKNESS (Inches)	DRYING TIME (Hours)	DENSITY Lbs/Cu. Ft.	REMARKS
A1	Rodmill once; Beat ½ hr.	1.75	40.0	9.34	No strength
A2	"	2.75	40.0	8.52	"
B1	Cooked at 50 lbs. pressure; 20% caustic; Beater ½ hr.	1.50	26.0	10.90	Much stronger than A1. A firm compact board
B2	"	1.25	26.0	8.59	"
C1	Cooked pulp from B1; Rodmilled twice; Jordan once.	1.50	24.0	7.46	Fibers short but well felted
C2	"	1.75	24.0	7.15	"
D1	Shredded and rodmilled twice; Beater ½ hr.	1.50	24.0	6.87	Hard Finish
D2	"	1.75	24.0	7.25	"
E1	No shredding; Rodmilled twice; Beater 1 hour	1.75	30.0	9.50	Good strength Long fibers.
E2	"	1.37	30.0	10.40	"
F1	Fermented pulp; Rodmilled twice; Beater 1 hour.	3.12	24.0	7.67	Very strong firm board
F2	"	2.00	24.0	8.10	"
G1	Water cook at 50# pressure; Rodmilled; Beater ½ hr.	2.00	24.0	5.21	A firm light board
G2	"	2.50	24.0	5.20	"
H1	Rodmilled; Beater 1 hr.	2.00	13.5	8.07	Vacuum of 12½" for 6½ hrs.
J1	Process like H1; No suction or pressing	2.50	34.0	9.13	Warped considerably
K1	"	2.50	48.0	7.34	"
L1	Rodmilled twice; Beater 1 hr.	6.00	72.0	7.53	Tough clear through
M1	Rodmilled twice; Beaten ½ hr. Jordan twice	2.00	24.0	5.41	Even texture; strong

(2). Board from the pith. Seidel (46) in 1926 removed the pith from cornstalks in order to produce a better grade of insulating board. He floated the pith away from the outer fiber. The pith was then subjected to a separate cooking process.

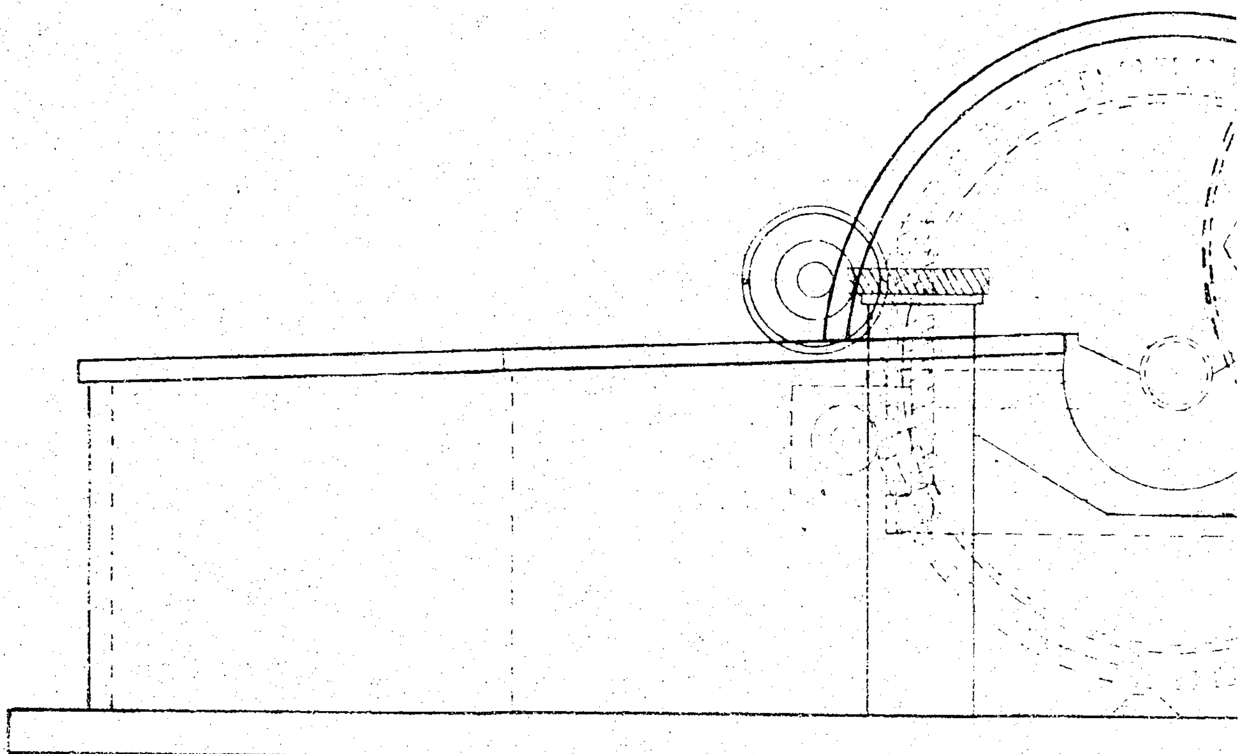
This same method was used for securing the pith. The entire operation was carried out in a beater of the ordinary paper pulp type. Disintegration was accomplished by brushing the shredded stalks in the beater for several hours. During this process the pith was brushed free from the fibers and floated to the surface of the water. A rotary washer equipped with a quarter inch screen lifted the pith from the water and deposited it upon a fine mesh screen located on the outside of the beater. See Plates No. 2_{II} to 5_{II}, pages 69 to 72.

This separator removed from eighty to eighty-five per cent of the pith from the cornstalk.

A series of runs was made in order to determine the best methods of producing a good refrigeration board. The pith was removed by hand and by machine. The boards were made either by cooking the pith with water or caustic or by using the uncooked pith. Different means of refining were used. See Table No. 2_{II}, page 73.

Pith separated by hand produced the lightest board. Good boards were produced from mechanically separated pith. Refin-

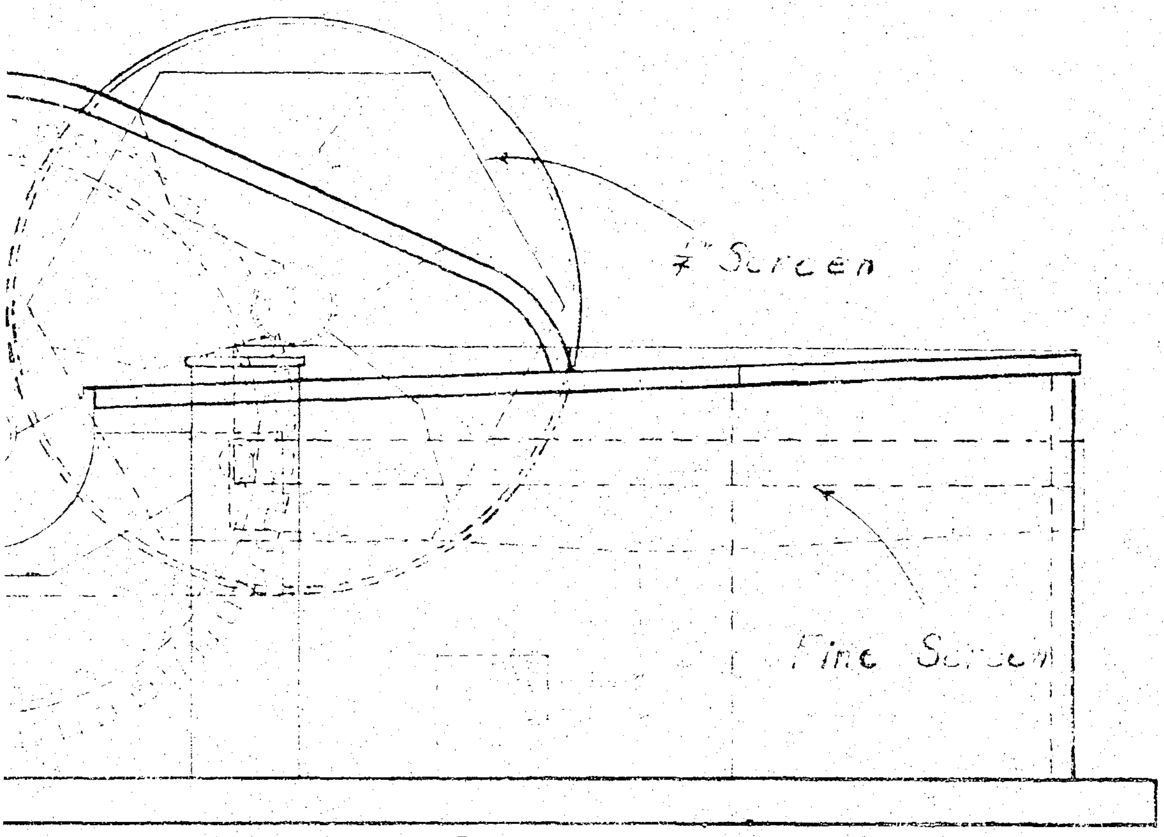
PLATE N



Front Vi

MACHINE

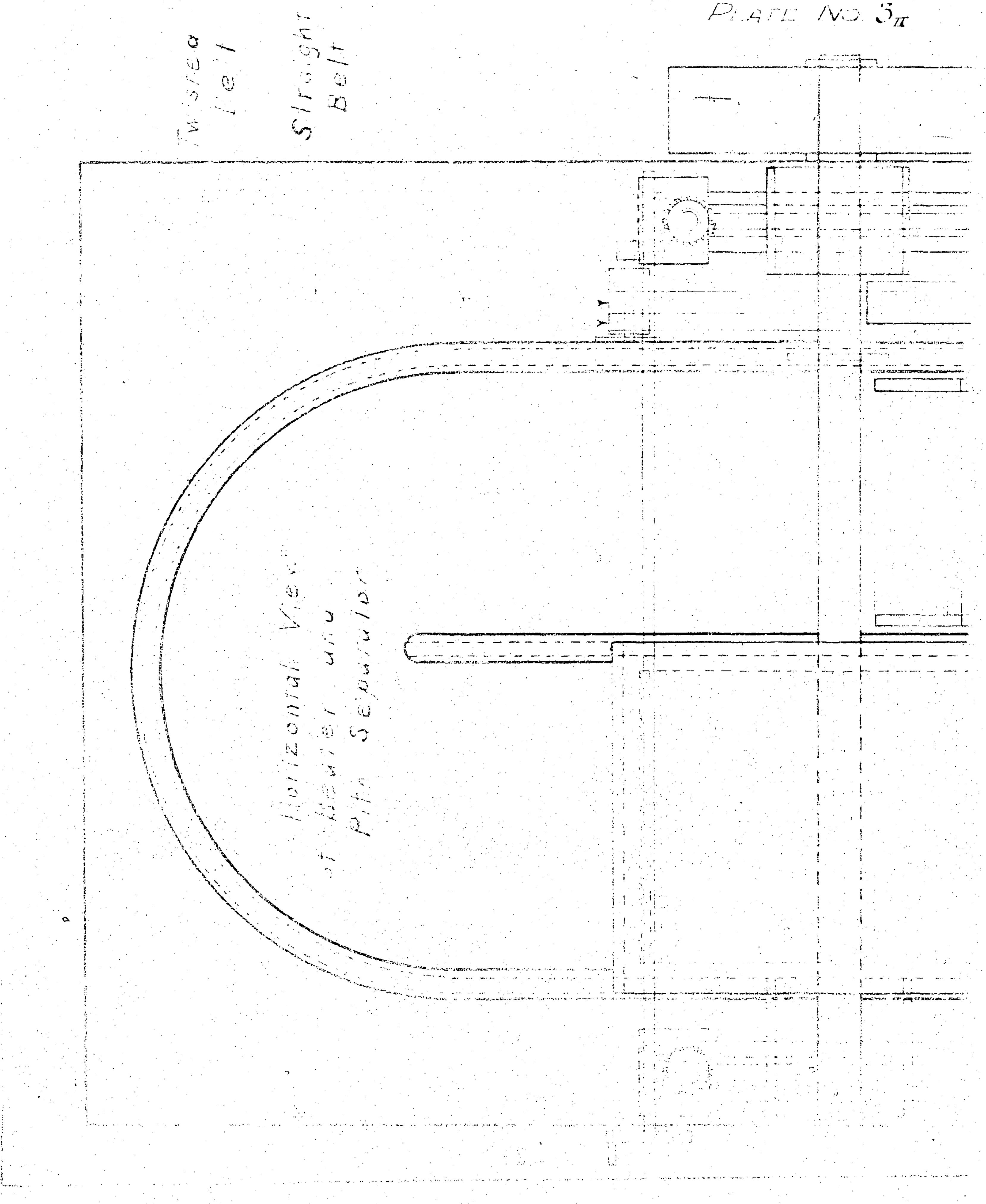
No. 2_{II}



...iew

...RPPING PITH.

PLATE NO 3$_{II}$


Twisted Belt
Straight Belt
Y Y
Horizontal View of Beater and Pith Separator

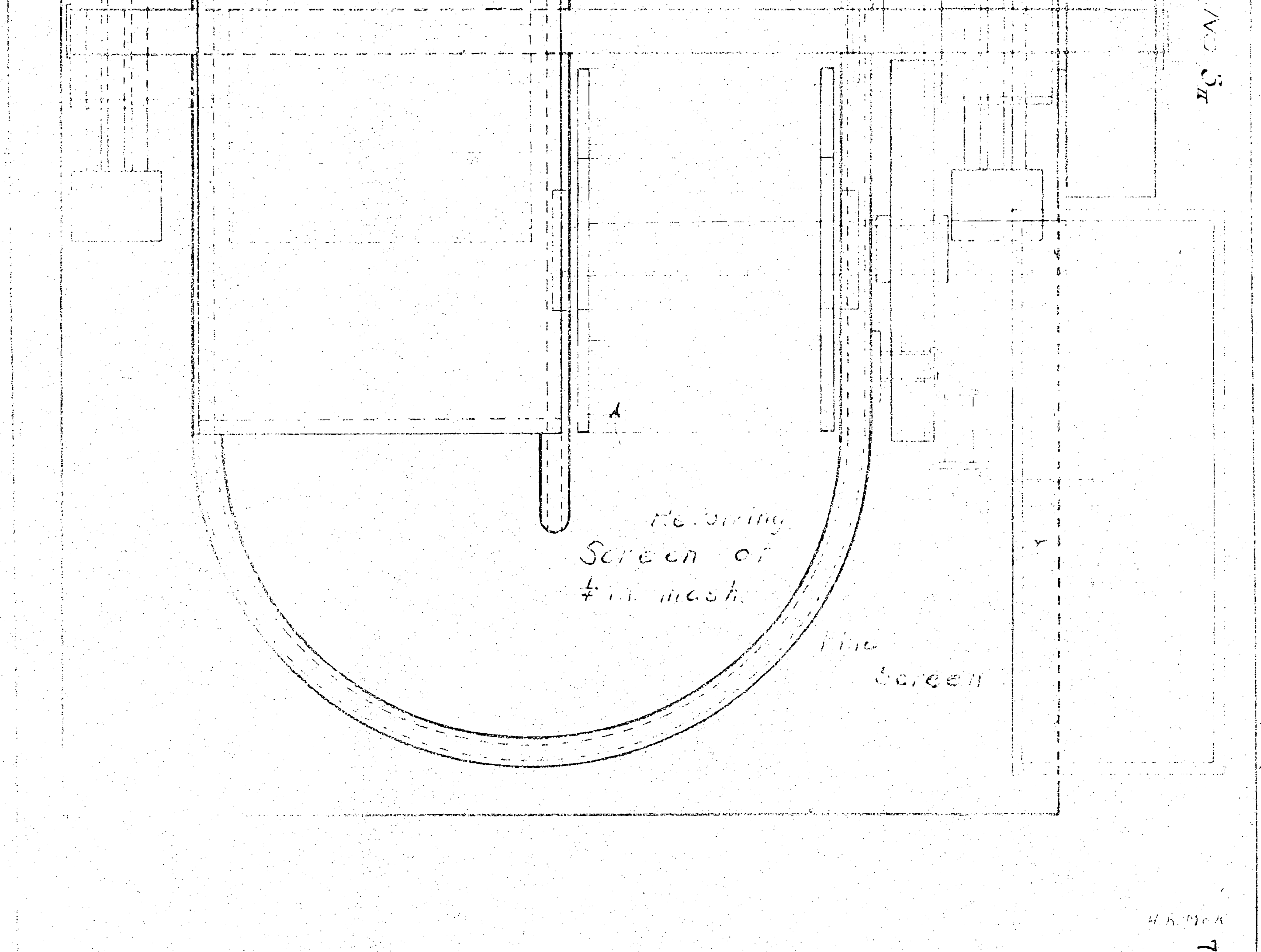
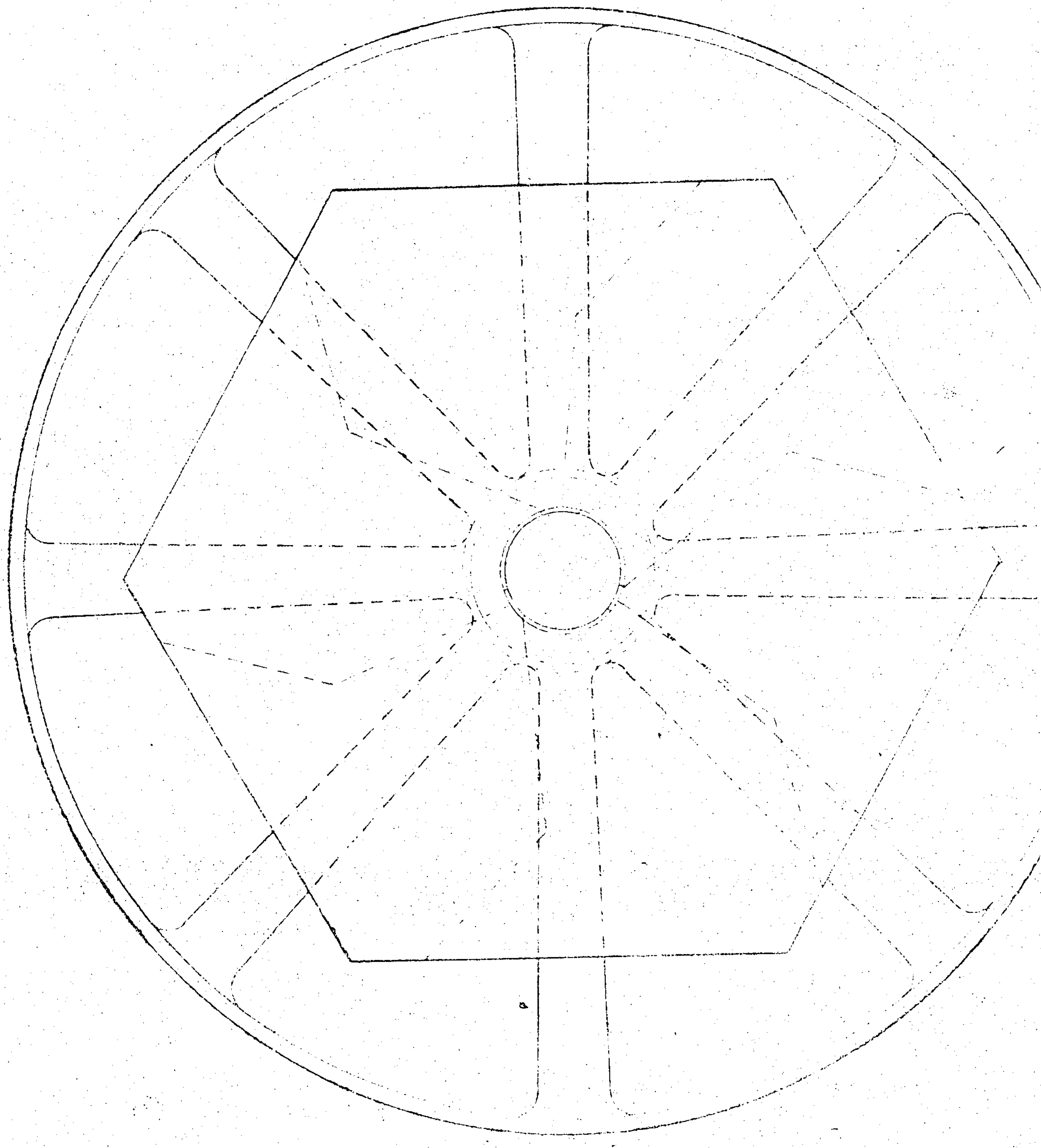
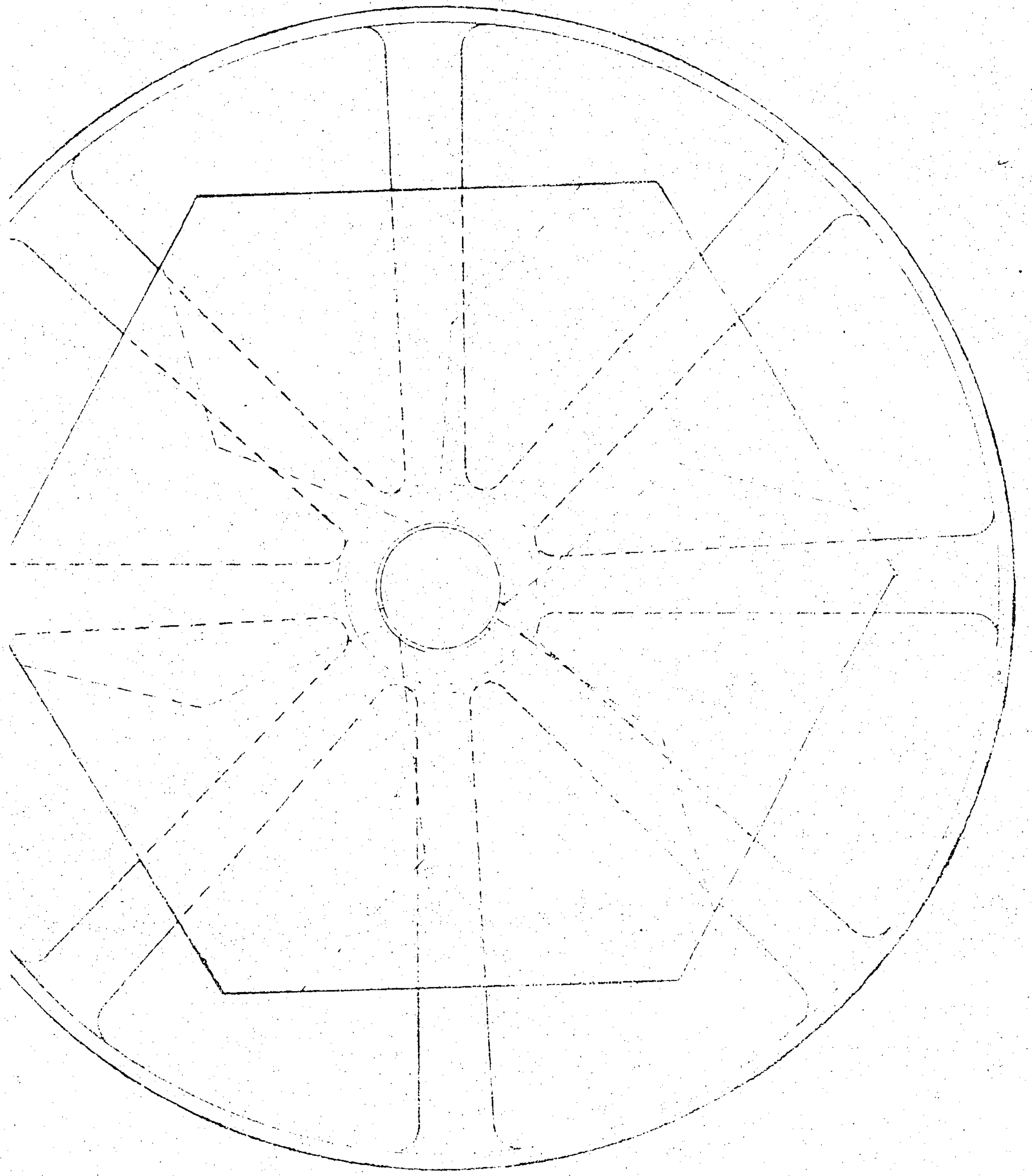

A
Screen of
4 in. mesh
Screen

PLATE NO. 4_{II}



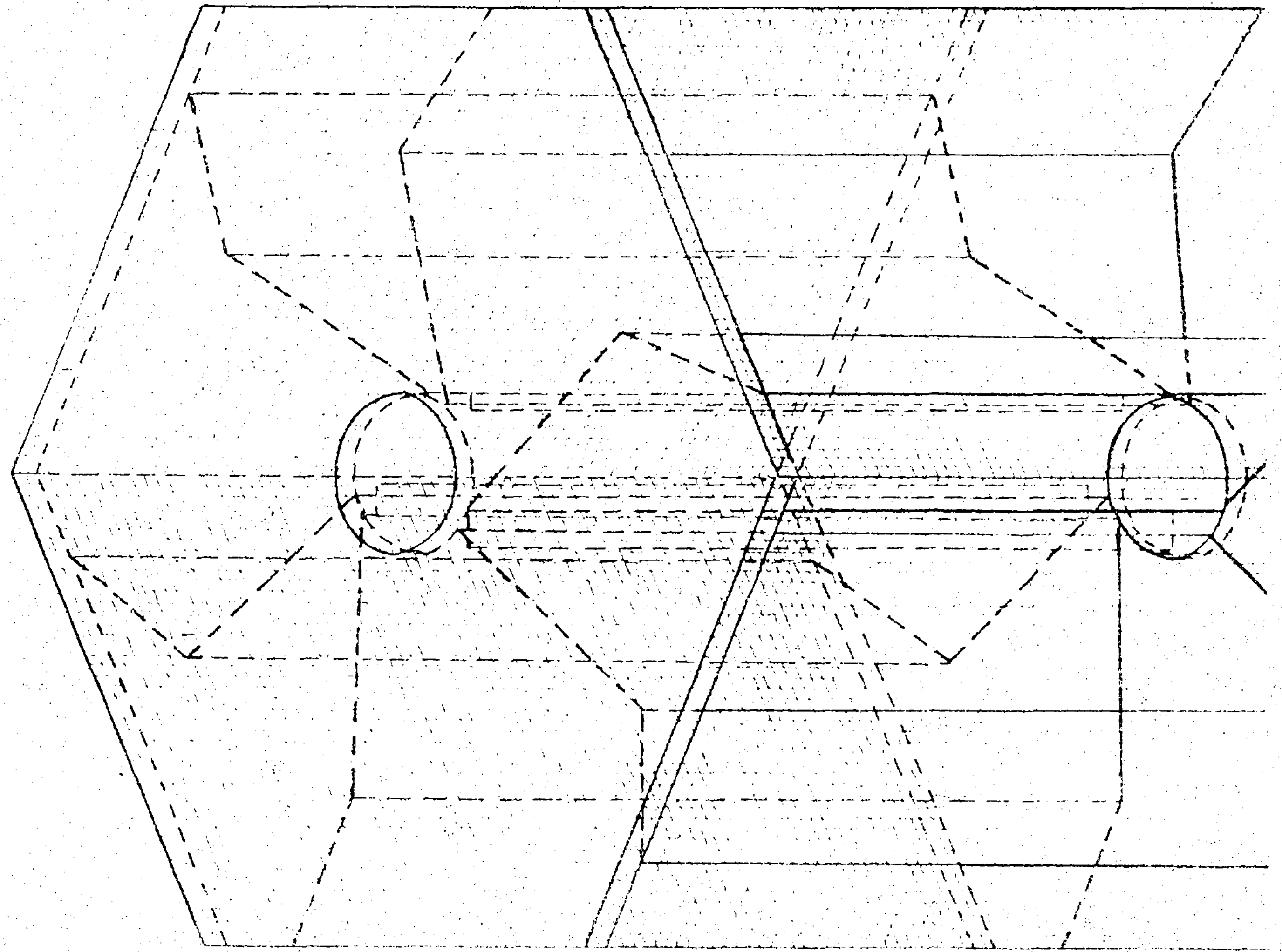
Pith Separator
End View

PLATE NO. 4II



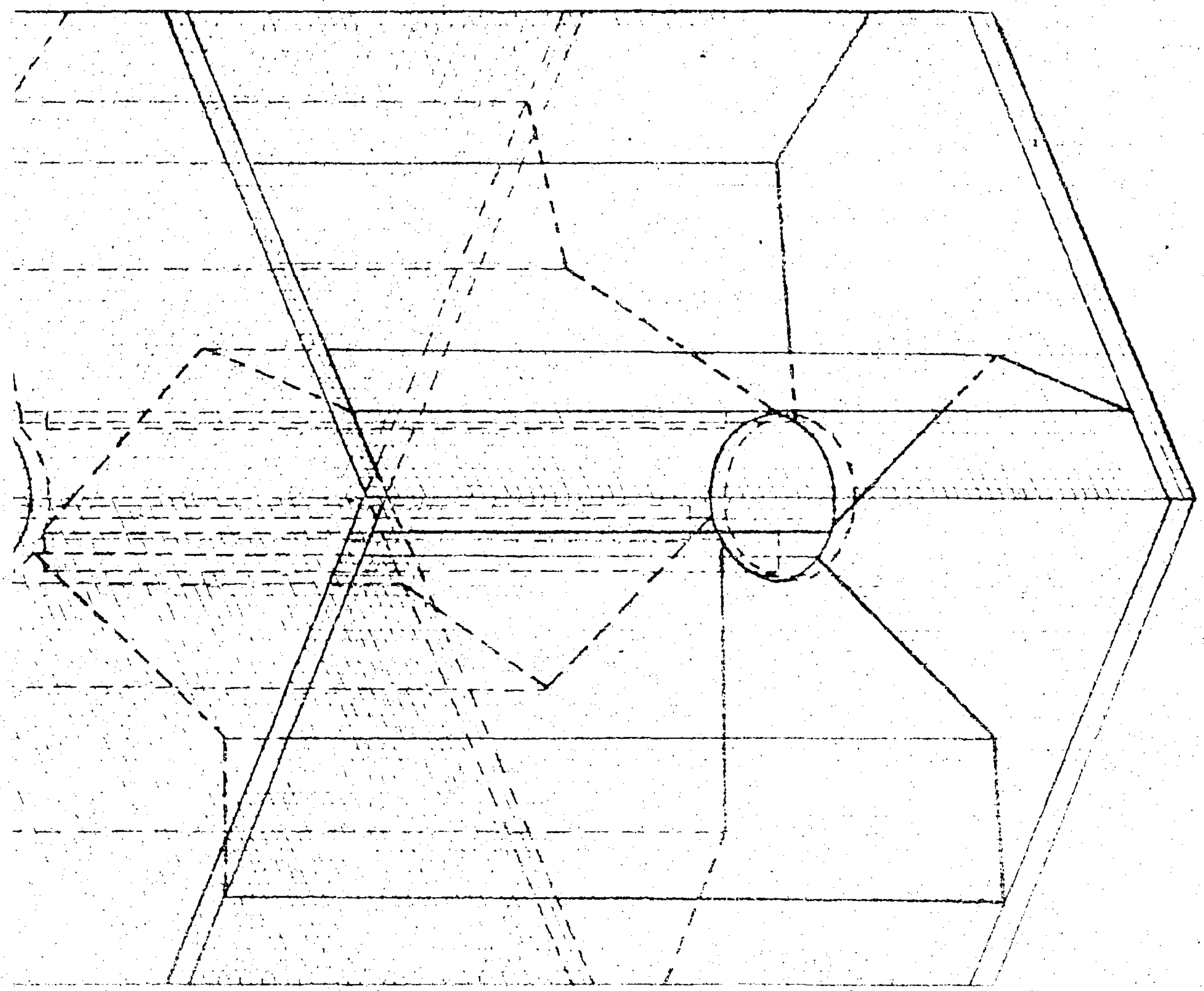
Pith Separator
End View

PLATE NO. 5 II



Pith Separator
Side View (Perspective

PLATE NO 5 II



Pith Separator
Side View (Perspective)

TABLE NO. 2_{II}

PREPARATION OF REFRIGERATION BOARD FROM PITH

PROCESS	DENSITY	STRENGTH	REMARKS
Mechanical separation; Beaten 2 hrs.		Weak	No formation
Cooked with lime; Beat 2 hrs.	5.01	Fair	Firm
Mechanical separation; Beat 2 hrs.	2.36	Low	Fine texture
Cooked with 10% caustic, 2 hrs. at 50# Beat 1 hr.	4.65	V. Good	Looked like cork
Separated by hand; Beat 15 min.	1.88	Weak	Very fine texture
Mechanical separation; Beat 15 min.	4.56	Fair	Good texture
Same as above, Pressed hard in hydraulic press	12.8	Strong	Very good texture
Mechanical separation; Beat 15 min. and jordaned	5.61	Fair	Good texture
Separated by hand; Beat ½ hr.; Jordaned	3.34	"	" "
Mechanical separation; Beat fine; Pressed	7.95	Strong	Fine texture
Mechanical separation; Beat 15 min.	4.14	"	" "
Mechanical separation; Cooked 2 hrs. 15% caustic; Jordaned	3.12	"	Fair texture
Mechanical separation; Cooked 2 hrs. with water; beat fine	5.70	"	Very good texture

ing in the jordan increased the strength and improved the texture. Cooking with chemicals improved the strength but increased the density.

b. Drying of refrigeration board

Since the pithboard is exceedingly porous, it absorbs moisture rapidly. Contact with water for only five minutes showed an absorption of over six hundred per cent. Therefore when the pith is formed into a board a large amount of moisture is present. It is very important to remove this water as cheaply as possible.

Various methods of drying were attempted such as air drying, vacuum drying, pressure drying, and electrical drying.

(1). Air drying. The wet mat, with edges exposed, was placed at atmospheric conditions. Since the humidity of the air determined largely the rate of drying, each loss in weight was based on a period of twenty-four hours at an average humidity of forty per cent. Two boards were made in this study. Each board was weighed every day for fifteen days. See Table No. 3_{II}, page 75, and Table No. 4_{II}, page 76.

More water was evaporated the first few days than during the last part of the run. The densities of the two boards

TABLE NO. 3 II

AIR DRYING OF PITH BOARD (RUN NO. 1)

DATE NO. 1	TIME	DRY BULB TEMP.	WET BULB TEMP.	% HUMIDITY	WEIGHT (GRAMS)	LOSS IN WEIGHT (GRAMS)	TIME INTERVAL (HOURS)	LOSS OF WT. BASIS OF 24 HOURS	AVERAGE HUMIDITY	LOSS OF WT. (40% HUMIDITY)
Jan. 27	11 30	84°F	63°F	49	5865					
28	1:30	83	60	18	4950	915	26	845.0	32.5	687.0
29	9:30	76	60	34	4583	367	20	440.0	26.0	286.0
30	11:00	79	65	47	4006	577	25	543.0	40.5	548.0
31	9:15	78	62	42	3569	437	22	472.0	44.5	525.0
Feb. 1	9:30	77	62	43	3130	439	24	434.0	42.5	461.0
3	[illegible]	82	64	37	2510	620	48	307.0	40.0	307.0
4	2:50	83	65	37	2350	160	28	135.0	37.5	124.5
5	1:20				2277	73	22	78.0	35.0	68.2
6	1:30	83	68	33	2214	63	24	62.7	35.0	54.9
7	10:00	85	67	39	2181	33	20	38.6	36.0	35.7
8	9:00	84	68	43	2165	16	23	16.7	41.0	17.1
10	10:00	85	65	33	2150	15	49	7.3	38.0	7.0
11	10:30	81	60	27	2150	0	24	0.0	30.0	0.0
12	8:45	85	69	44	2150	0	22	0.0	35.5	0.0

Weight of Plate — 1852 grams
Weight of Board — 306 grams
Size of Board — $15\frac{3}{8}'' \times 15\frac{3}{8}'' \times 1''$
Volume of Board — 236 cubic inches
Density of Board — 0.00285 pounds per cubic inch
Time of Drying — 14 days

TABLE NO. 4 II

AIR DRYING OF PITH BOARD (RUN NO. 2)

DATE NO. 1	TIME	DRY BULB TEMP.	WET BULB TEMP.	% HUMIDITY	WEIGHT (GRAMS)	LOSS IN WEIGHT (GRAMS)	TIME INTERVAL (HOURS)	LOSS OF WT. BASIS OF 24 HRS.	AVERAGE HUMIDITY	LOSS OF WT. (40 % HUMIDITY)
Jan. 27	11:30	84°F	69°F	47	[illegible]					
28	1:30	83	60	18	5165	585	26.00	540.0	32.5	438.0
29	9:30	76	60	34	5200	265	20.00	318.0	26.0	207.0
30	11:00	79	65	47	4635	565	25.50	532.0	40.5	538.0
31	9:15	78	62	42	4252	383	22.25	413.0	44.5	460.0
Feb. 1	9:30	77	62	43	3857	395	24.50	390.0	42.5	414.0
3	10:00	82	64	37	3075	782	48.50	386.0	40.0	386.0
4	2:30	83	65	37	2813	262	28.50	221.0	37.0	205.0
5	1:20				2682	131	22.17	139.8	35.0	12[illegible].5
6	1:30	89	68	33	2565	11[illegible]	24.50	116.2	35.0	101.5
7	10:00	85	67	39	2475	90	20.50	105.5	36.0	92.3
8	9:00	84	68	43	2330	45	23.00	46.9	41.0	48.1
10	10:00	85	65	33	2295	35	49.00	17.15	38.0	16.3
11	10:30	81	60	27	2245	45	24.50	44.2	30.0	33.1
12	8:45	85	69	44	2232	13	22.25	13.9	35.5	12.3

Weight of Plate - 1941 grams
Weight of Board - 289 grams
Size of Board - $15\frac{3}{8}'' \times 15\frac{3}{8}'' \times 1\frac{1}{16}''$
Volume of Board - 250 cubic inches
Time of Drying - 15 days
Density of Board - 0.00255 Pounds per cubic inch

were very similar. The curves showing the rate of drying of the two boards resemble each other very closely. See Curves No. 1_{II}, page 78, and No. 2_{II}, page 79.

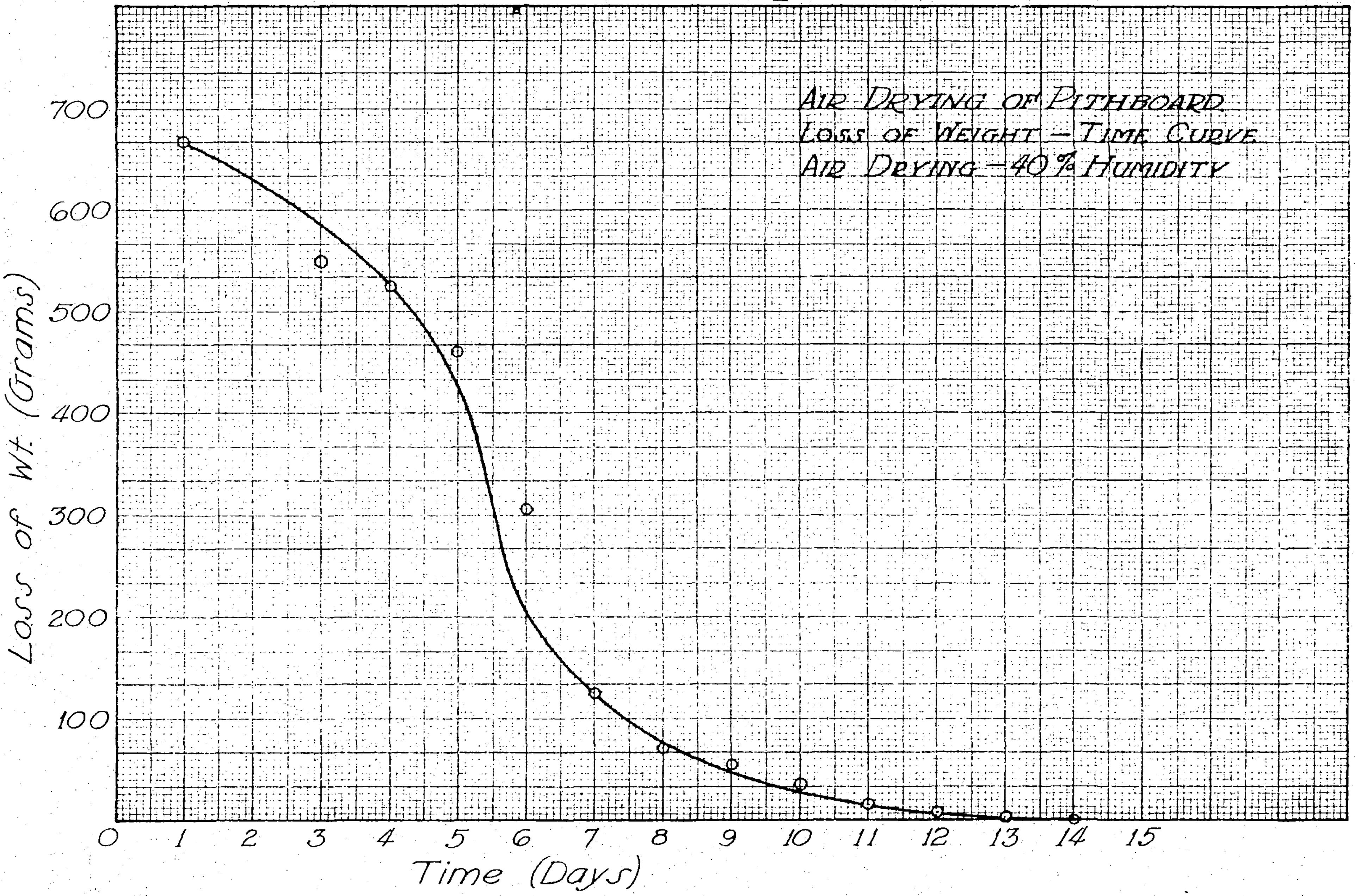
(2). Steam oven drying. The steam losses for this oven were secured by weighing the condensate for several hours. See Table No. 5_{II}, page 80.

The average heat loss per minute was equal to $\frac{39330}{32}$ or 106 grams. After securing the heat losses for the empty oven the steam oven was tested, without the aid of vacuum. Six boards were dried during the experiment. Each surface was covered with a copper screen and a perforated galvanized iron plate. The weight of the six boards for run number one were:

1	-	16.5 pounds
2	-	17.0 "
3	-	17.75 "
4	-	20.0 "
5	-	20.0 "
6	-	15.25 "

This weight included the total weight of the plates, screen, water, and pith. The sum of the six boards was

CURVE NO. 1_{II}



Form F-5

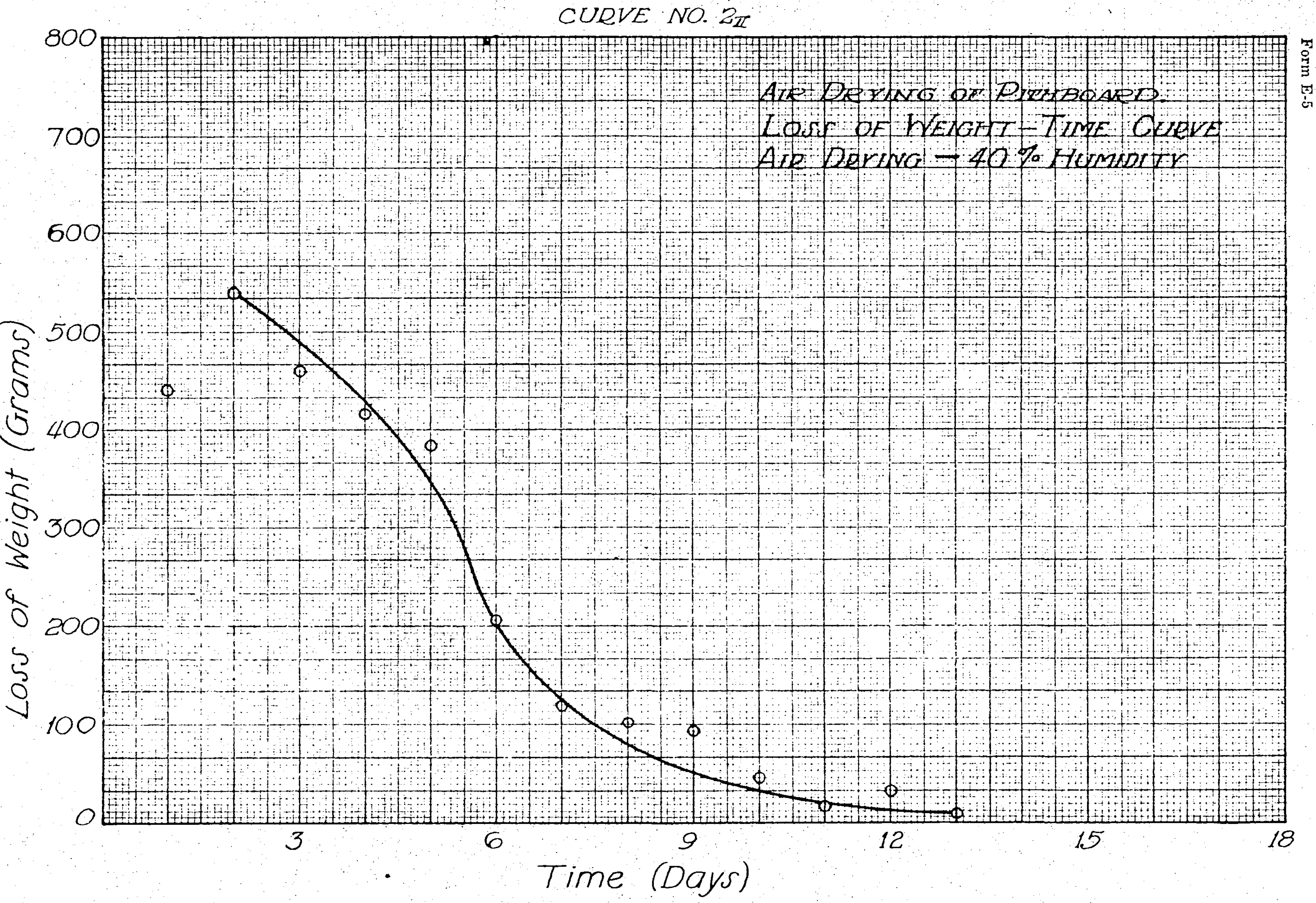

CURVE NO. 2II
AIR DRYING OF PITHBOARD.
LOSS OF WEIGHT – TIME CURVE
AIR DRYING – 40 % HUMIDITY
Loss of Weight (Grams)
0
100
200
300
400
500
600
700
800
3
6
9
12
15
18
Time (Days)
Form E-5

TABLE NO. 5_II

STEAM LOSSES FROM STEAM DRYER

DATE	TIME	TIME INTERVAL (MINUTE)	WEIGHT OF BUCKET AND CONDENSATE (GM)	WEIGHT OF CONDENSATE (GMS)	RATE GM. PER MIN	STEAM PRESSURE LBS./SQ. IN.	AVERAGE PRESSURE LBS./SQ. IN.	TEMP. °C.
Jan. 20, '30	1:30	0				49.5		104.6
	2:05	35	4605	3335	95.2	49.0	49.25	104.6
	2:30	25	5200	3930	157.0	49.0	49.00	104.6
	3:00	30	3272	2003	66.7	50.0	49.50	105.0
	3:30	30	3270	2000	66.7	50.0	50.00	105.0
	4:00	30	2240	1970	65.7	50.0	50.00	105.0
Jan. 20, '30	8:20					49.5		103.0
	8:58	38	4675	3313	87.2	49.5	49.50	103.0
	9:28	30	4205	2205	73.3	40.5	40.50	99.0
	9:50	22	5616	4254	193.0	44.5	42.50	100.5
	10:20	30	5263	3997	133.0	47.0	45.75	101.5
	10:55	35	6740	4740	135.0	50.0	48.50	103.0
	11:25	30	4600	3255	108.0	53.0	51.50	104.0
	11:45							
	1:15	90	11160	7160	79.5	47.0	50.00	103.0
Feb. 1, '30	9:00					39.0		
	9:35	35	4253	2253	64.3	42.0	40.50	101.0
	10:05	30	6090	4070	135.5	49.0	45.50	102.0
	10:35	30	7022	5022	167.0	48.0	48.50	103.0
	11:05	30	8304	6304	209.5	51.0	49.50	103.5
	11:35	30	8024	6024	200.5	47.0	49.00	103.0
	1:30	115	12297	10297	89.6	51.0	49.00	105.0

TABLE NO. 5$_{II}$

STEAM LOSSES FROM STEAM DRYER (Continued)

DATE	TIME	TIME INTERVAL (MINUTE)	WEIGHT OF BUCKET AND CONDENSATE (GM)	WEIGHT OF CONDENSATE (GMS.)	RATE GM PER MIN.	STEAM PRESSURE LBS/SQ. IN.	AVERAGE PRESSURE LBS./SQ. IN.	TEMP. °C.
	2:00	30	4127	2127	70.8	52.0	51.5	105.0
	2:30	30	4821	2821	93.8	50.0	51.0	104.0
	3:00	30	4583	2583	86.2	50.0	50.0	104.0
	3:30	30	5538	3538	118.0	47.0	48.5	103.5
	4:00	30	5408	3408	113.7	49.0	48.0	104.0
	4:30	30	5093	3093	102.8	50.0	49.5	104.0
Feb. 4, '30	10:07					39.0		100.0
	10:37	30	2860	1100	36.6	38.0	38.5	99.0
	11:07	30	4935	3175	105.8	45.0	41.5	100.5
	11:37	30	6590	4830	161.0	48.0	46.5	102.0
	1:30	113	15269	13510	135.0	54.0	51.0	104.0
	2:00	30	4852	3490	116.3	46.0	50.0	104.0
	2:30	30	4535	2775	92.5	49.0	47.5	104.0
	3:00	30	4038	2676	89.2	51.0	50.0	105.0
	3:24	24	3536	1776	74.0	49.0	50.0	104.0
	3:54	30	4960	2960	98.7	48.0	48.5	104.0
Feb. 7, '30	9:24					36.0		199.5
	9:54	30	4200	2240	74.7	41.0	38.5	100.0
	10:24	30	4485	2545	84.8	46.0	43.5	102.0
	10:54	30	4075	2115	70.5	47.5	46.75	102.0
	11:24	30	4405	2445	81.5	51.0	49.75	102.0

105.5 pounds. See Table No. 6_{II}, page 83.

The rate of steam consumption per hour =

$$\frac{\text{Net weight of condensate (60)}}{\text{Time elapsed (minutes)}} = \left(\frac{4329}{30} - 106\right)(60)$$

$$= 2300$$

Weight of copper screens	=	5.15 pounds
" of iron plates	=	52.2 pounds
Entering temperature	=	70°F.
Average Temperature of drier	=	212°F.
Difference in temperature	=	142°F.
Specific Heat of copper	=	0.093
Specific Heat of iron	=	0.013
Specific Heat of water	=	1.0
Specific Heat of pith	=	0.37
Weight of pith	=	2.5 pounds
Weight of water	=	45.65 "

Sensible Heat

Copper (142)(0.093)(5.15)	=	68.2	B.T.U.
Iron (142)(0.113)(52.2)	=	837.5	B.T.U.
Pith (142)(0.37)(2.5)	=	13	B.T.U.
Water (142)(1)(45.65)	=	6490	B.T.U.
Total		7408.7	B.T.U.

Steam used for sensible heat $= \frac{7408.7}{970} = 7.64\ \%$

TABLE NO. 6$_{II}$

DRYING OF PITHBOARD IN STEAM OVEN.

DATE	TIME	NET WT. OF CONDENSATE	STEAM PRESSURE	TIME INTERVAL (MINUTE)	RATE OF STEAM CONSUMPTION GMS./MIN.
Feb. 27 1930	8:25		51.0		
	8:55	4329	49.0	30	2300
	9:25	5850	44.0	30	5540
	10:00	3634	38.0	35	1100
	10:25	5050	40.0	25	5960
	10:55	9136	45.0	30	12100
	11:25	9530	49.0	30	12940
	11:55	10024	50.0	30	13888
	12:25	10241	51.5	30	14322
	12:55	10009	50.0	30	13858
	1:25	8040	50.0	30	9920
	1:55	6665	50.0	30	7170
	2:25	7297	47.0	30	8434
	2:55	7527	48.0	30	8894
	3:25	7975	51.0	30	9740
	5:05	16560	48.0	100	3570
	7:15	24340	47.0	100	8310
	10:15	26400	51.5	180	2430
Feb. 28 1930	12:15	13310	51.0	120	290
	2:15	12470	50.0	120	0
	4:15	12110	50.0	120	0
	6:00	10890	50.0	105	0
	8:00	12890	49.0	120	0
	9:20	7930	48.5	80	0
Total		242 237		1465	

Steam oven losses $= \frac{106}{454}$ (1465) = 342 pounds

Total steam used $= \frac{242,237}{454}$ = 532.5 pounds

Steam used in evaporation = 532.5 - 342 - 7.64

= 182.86 pounds

Efficiency of drier $= \frac{45.65}{182.86}$ = 24.9 %

The actual drying rate may be seen by observing Curve No. 3_{II}, page 85. The maximum drying rate was reached when one-fifth of the drying time had elapsed. The curve shows a slow rate of drying during the latter part of the run. Several rises and falls in pressure indicate points off the curve. See Table No. 7_{II}, page 86, for results of run number two.

The total weight of boards used was 105.25 pounds.

The total time was 1430 minutes.

Steam used for sensible heat equals same as run one, 7.64 pounds.

Steam over losses $= \frac{106}{454}$ (1430) = 333.5 pounds

Total steam used $= \frac{189,890.5}{454}$ = 418 pounds

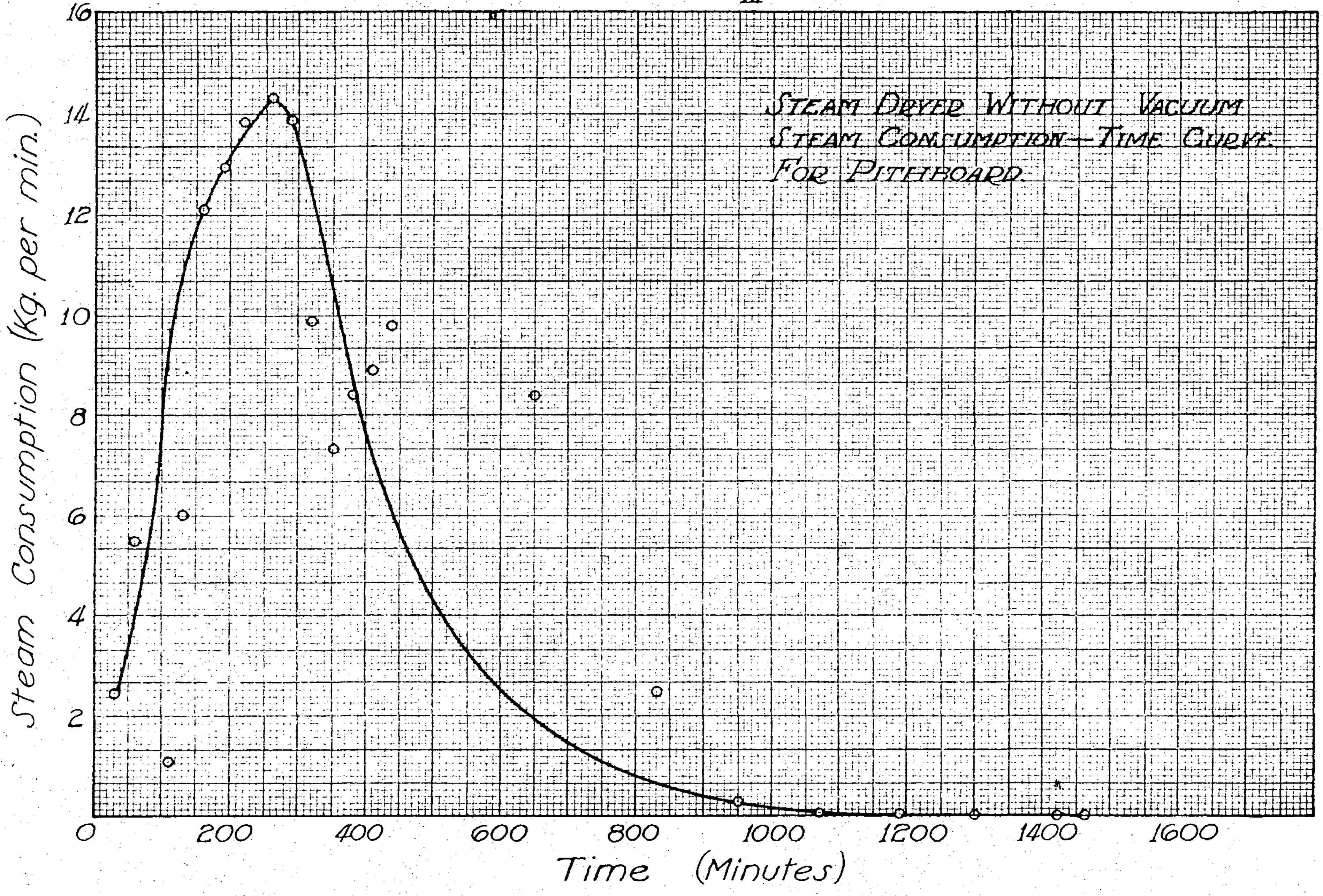
Weight of pith = 1950 grams = 4.29 pounds

Weight of water removed = 43.61 pounds

Steam used in evaporation = 418 - 333.5 - 7.64

= 76.86 pounds

CURVE NO. 3III



Form E-5

TABLE NO. 7$_{II}$

DRYING OF PITHBOARD IN STEAM OVEN.

DATE	TIME	TIME INTERVAL (MINUTE)	NET WEIGHT OF CONDENSATE (GRAMS)	STEAM PRESSURE (POUNDS)
Mar. 6	8:15			
	8:45	30	11215	45.0
	9:15	30	5313	50.5
	9:45	30	4510	47.0
	10:15	30	3950	51.0
	10:45	30	5980	53.0
	11:15	30	3485	51.0
	11:45	30	5653	50.0
	12:55	70	9058	52.5
	1:15	20	4064	50.0
	1:45	30	6221	47.5
	2:15	30	3695	47.0
	2:45	30	4212	42.0
	3:15	30	3530	42.0
	3:45	30	3976	48.0
	4:15	30	3503	46.5
	4:45	30	4323	50.0
	5:30	45	3875	47.0
	7:25	115	13560	49.0
	9:45	140	17390	54.0
	11:50	125	15710	59.0
Mar. 7	2:00	130	15050	54.0
	4:00	120	13630	56.0
	6:00	120	13540	56.0
	8:05	125	14766	46.0

Efficiency of dryer $= \frac{43.61}{76.86} = 56.7\ \%$

The boards were not dry when removed from the oven. This accounted for the higher efficiency of the dryer for the last traces of water require much more time in drying than does the first part removed. The steam pressure fluctuated decidedly causing a very uneven discharge of condensate. Consequently, the rate of steam consumption was difficult to secure.

(3). Vacuum drying. These two runs were made in the same oven but vacuum was used during the drying. See Table No. 8_{II}, page 88, for results of run number one. The steam oven losses for vacuum drying were equal to 72.4 grams per minute.

Losses due to radiation = (72.4)(717) = 51,800 grams

Steam used for drying $= \frac{77151 - 51800}{454} = 55.8$ pounds

Weight of pith = 4.5 pounds

Weight of screens = 5.5 pounds

Weight of plates = 53.25 pounds

Total weight = 102.75 pounds

Weight of water removed = 102.75 - 63.25 = 39.5 pounds

Efficiency $= \frac{39.5}{55.8}(100) = 70.7\ \%$

These boards were slightly damp when removed. Therefore the efficiency would be lowered somewhat for bone dry boards. See Curve No. 4_{II}, page 89, for the characterists of this drying process. See Table No. 9_{II}, page 90, for results of

TABLE NO. 8_{II}

VACUUM DRYING OF PITHBOARD.

DATE	TIME	TIME INTERVAL (MINUTE)	WEIGHT OF CONDENSATE (GRAMS)	STEAM PRESSURE (POUNDS)	VACUUM (INCHES OF MERCURY)
Mar. 10	8:15			50.0	
	8:45	30	9626	50.0	20.0
	9:15	30	1773	50.0	20.0
	9:45	30	1681	49.0	20.0
	10:15	30	2589	43.0	20.0
	10:45	30	2475	46.0	21.0
	11:15	30	3497	46.0	21.0
	11:45	30	5086	47.5	20.5
	12:15	30	3383	48.0	20.5
	12:45	30	2249	50.0	20.7
	1:15	30	3724	48.0	20.5
	1:45	30	3227	41.0	20.5
	2:15	30	2929	41.0	20.5
	2:45	30	4231	45.0	16.5
	3:15	30	4405	47.0	15.0
	3:45	30	6356	46.0	17.5
	4:15	30	2270	49.5	20.0
	4:45	30	2270	46.0	21.0
	5:15	30	2667	45.0	20.0
	5:45	30	1530	46.0	20.0
	7:10	85	4767	46.0	20.0
	8:12	72	6356	47.0	20.0
Total		717	77151		

Form E-5

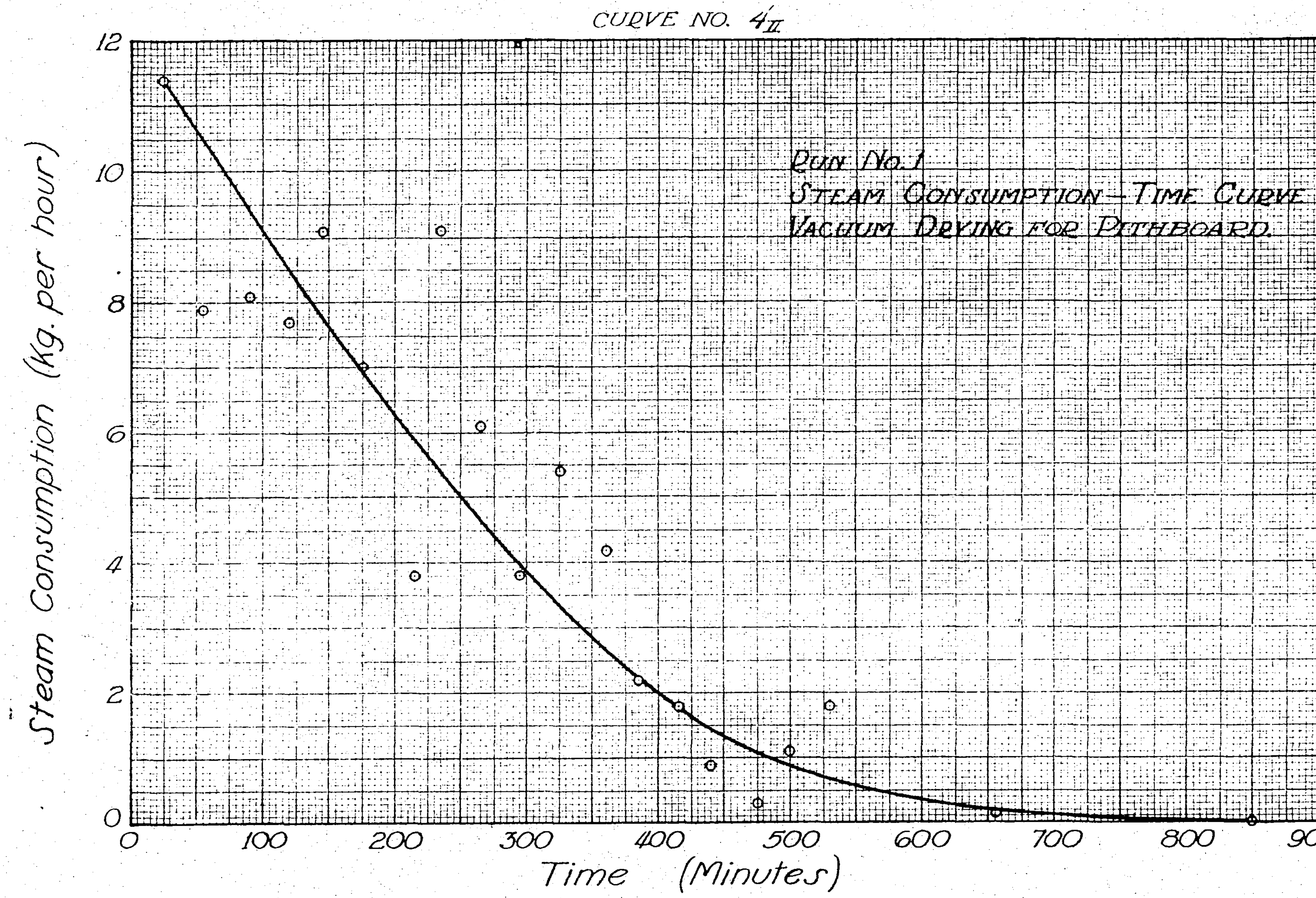

CURVE NO. 4'II
RUN No. 1
STEAM CONSUMPTION - TIME CURVE
VACUUM DRYING FOR PITHBOARD.
Steam Consumption (kg. per hour)
0
2
4
6
8
10
12
Time (Minutes)
0
100
200
300
400
500
600
700
800
900

TABLE NO. 9_{II}.

VACUUM DRYING OF PITHBOARD.

DATE	TIME	TIME INTERVAL (MINUTES)	WEIGHT OF CONDENSATE (GRAMS)	VACUUM (INCHES OF MERCURY)	STEAM CONSUMPTION GMS/HR.	STEAM PRESSURE LBS/SQ.IN.
Mar.13	8:20					
	8:45	25	6583	19	11430	50.0
	9:15	30	6129	20	7900	51.0
	9:60	35	6242	20	8130	50.5
	10:15	25	4994	20	7630	49.5
	10:45	30	4743	20	9136	50.0
	11:15	30	5675	20	7000	50.0
	11:55	40	5448	20	3830	50.0
	12:15	20	4483	20	9099	51.0
	12:45	30	5221	20	6090	52.5
	1:15	30	4086	20	3820	51.0
	1:45	30	4880	20	5410	48.0
	2:20	35	4994	20	4220	46.0
	2:45	25	2724	15	2190	45.0
	3:15	30	3064	15	1780	45.0
	3:45	30	2610	20	870	45.0
	4:20	35	2724	20	318	46.0
	4:45	35	2156.5	20	1065	50.0
	5:15	30	3064.5	20	1780	47.5
	5:45	30	4767	18	5180	52.0
	6:15	30	4540	18	4730	47.5
	7:25	70	5230	16	137	53.0
	10:30	1[illegible]5	13393	20	0	50.0
Total		850	109750			

run two.

The steam oven losses = (72.4)(850) = 61,600 grams

Weight of drying steam = $\frac{109,750 - 61,600}{454}$ = 105.5 pounds

Weight of pith = 3.5 pounds

Weight of water removed = 46.25 pounds

Efficiency = $\frac{46.25}{105.5}$ (100) = 43.8 %

$$\text{Steam consumption} = \frac{\text{Wt of condensate} - (\text{steam oven losses})(\text{time})}{\text{time}}(60)$$

Calculation for first line of table =

$$\frac{6,583 - (72.4)(25)}{25}(60) = 11,430 \text{ grams per hour}$$

(4). Forced air drying. A Proctor and Schwartz dryer was next used for drying the pith board. This dryer differed from the previous dryer in that hot air was forced over the board thus wearing away the film of moisture surrounding the board and at the same time carrying away the water vapor. The first run was made on two sixteen inch square pith boards. Screens and iron plates were placed on both the top and the bottom of each board. The humidity of the exit air was recorded by wet and dry bulb thermometers.

Run two was made similar to run one except the pith was molded into a large board which rested directly on the screen of the dryer tray. This board did not have a plate on top.

No evidence of warping was noticed during the drying process and an excellent board was produced. See Table No. 10_{II}, page 93.

The board dried in a much shorter time than it did with either vacuum or steam drying. The quality of the board was good. See Table No. 11_{II}, page 94, for the results of run two. This board was thicker than the previous run but required only a few hours more of drying. See Curves No. 5_{II} and 7_{II}, pages 95 and 96, for the drying rate of the pith boards in the Proctor and Schwartz dryer. The two curves are very similar. See Curve No. 6_{II} and Curve No. 8_{II}, pages 97 and 98, for the relation between humidity, in pounds of water per pound of bone dry air, and time in minutes. The two curves varied widely. This error was accounted for by considering the fact that the temperature of the inlet air was eleven degrees lower for the first run.

(5). Drying by electricity. A specially designed platen, Plate No. 6_{II}, page 99, was used for this experiment. Runs were made using various thickness of boards but in no case could the time be reduced to a short enough time to be commercial.

TABLE No. 10_{II}

DRYING OF PITHBOARD IN PROCTOR AND SCHWARTZ DRIER.

TEMPERATURE, °F			HUMIDITY (% WATER VAPOR PER LB. OF BONE DRY AIR)	TIME	TOTAL WT. (GRAMS)	LOSS OF WT. (GRAMS)
OUTLET	DRY BULB	WET BULB				
180.0	209.0	107	0.027	2:21	13858	
194.5	229.0	116	0.041	2:31	13729	129
200.0	237.0	120	0.050	2:41	13542	187
206.0	241.0	124	0.059	2:51	13291	251
207.0	242.5	126	0.065	3:01	12988	303
208.0	243.0	129	0.075	3:11	12757	231
208.0	242.5	132	0.088	3:21	12485	302
207.0	241.5	135	0.102	3:31	12148	307
207.0	240.5	129	0.076	3:41	11888	260
207.0	241.0	129	0.076	3:51	11588	300
206.5	242.0	132	0.085	4:01	11293	295
207.5	243.0	129	0.076	4:11	11014	279
207.5	243.0	128	0.070	4:21	10761	253
210.0	244.0	128	0.070	4:31	10488	273
210.0	244.0	129	0.074	4:41	10211	277
209.5	244.0	128	0.070	4:51	9943	268
209.0	246.0	126	0.066	5:01	9688	253
209.0	247.0	126	0.066	5:11	9421	267
210.0	247.0	126	0.066	5:21	9158	263
212.0	249.0	126	0.065	5:31	8940	218
212.0	250.0	125	0.061	5:41	8680	260
212.0	249.0	123	0.055	5:51	8490	190
211.0	248.0	123	0.055	6:01	8351	139
212.0	249.0	122	0.052	6:11	8219	132
213.0	249.0	122	0.052	6:21	8121	96
214.0	248.0	122	0.052	6:31	8045	76
212.5	250.0	122	0.052	6:41	8000	45
214.0	250.5	121	0.051	6:51	7931	68
212.0	251.0	121	0.051	7:01	7900	31
214.5	251.0	123	0.053	7:11	7859	41
214.5	253.0	122	0.051	7:21	7830	29
214.5	254.0	122	0.051	7:31	7814	16
214.0	252.0	121	0.050	7:41	7802	12
214.0	253.0	124	0.053	7:51	7800	2
214.0	253.0	120	0.049	8:01	7795	5
214.5	254.0	122	0.051	8:31	7795	0

Weight of pith = 600 grams
Thickness = 0.075 inches
Loss of Weight = 13,858 − 7,795 = 6064 grams of water
Time required = 5 hours, 25 min.
Inlet Air Temperature 70° F

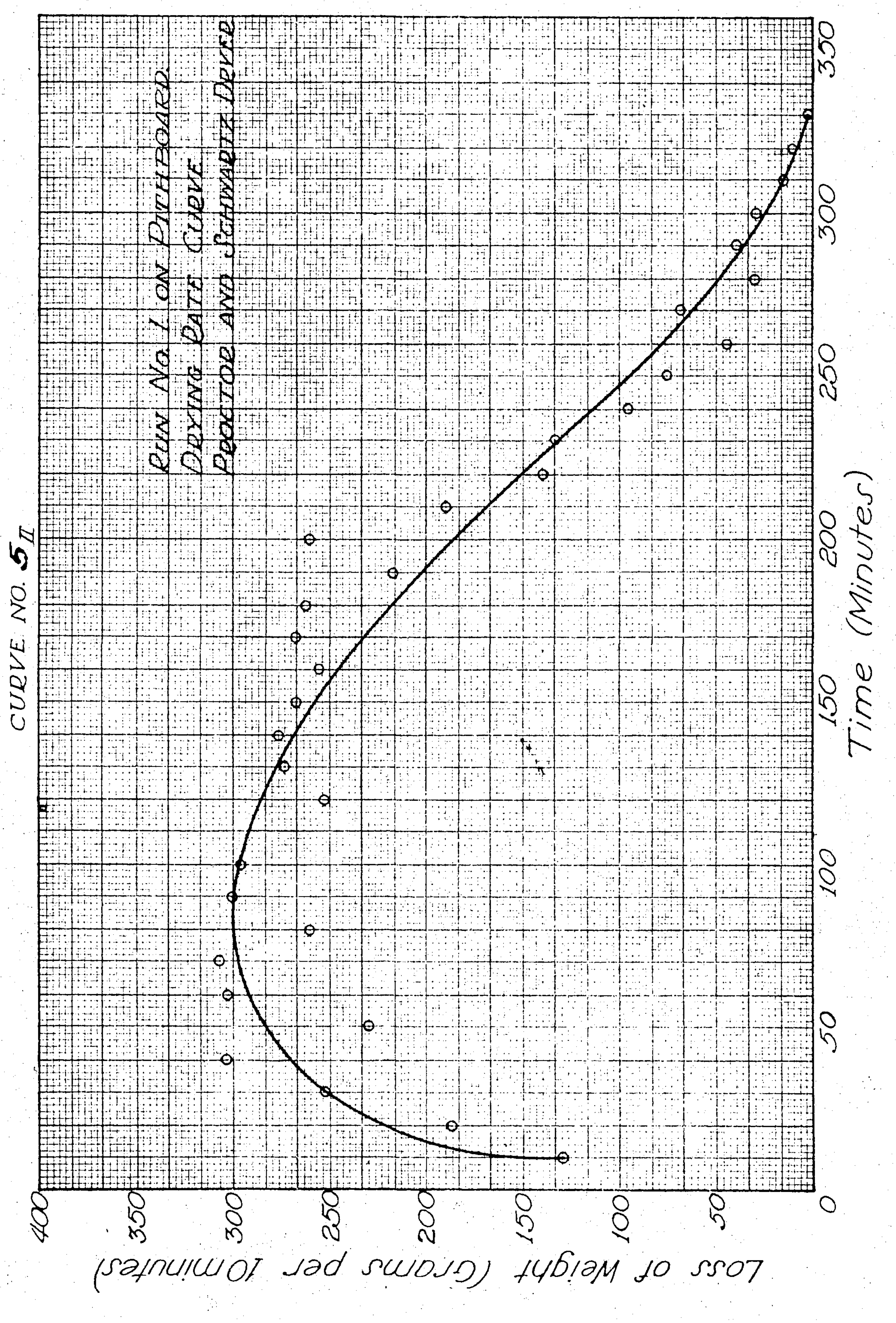
TABLE NO. 11_{II}

DRYING OF PITHBOARD IN PROCTOR & SCHWARTZ DRIER

TEMPERATURE, °F.			HUMIDITY (% WATER VAPOR PER LB. OF BONE-DRY AIR)	TIME	TOTAL WT. (GRAMS)	LOSS OF WT. (GRAMS)
OUTLET	DRY BULB	WET BULB				
196	212	115	0.045	9:27	12588	
201	220	130	0.055	9:35	12361	227
205	223	122	0.059	9:45	12021	340
209	227	125	0.067	10:00	11488	533
212	231	126	0.068	10:15	11008	580
215	235	125	0.065	10:30	10463	545
216	236	126	0.066	10:45	9936	527
216	236	126	0.066	11:00	9303	533
216	237	130	0.07	11:15	8908	495
219	239	128.5	0.07	11:30	8265	643
219	241	127	0.069	11:45	7785	480
228	250	122	0.051	1:02	5700	2085
230	252	121	0.050	1:15	5400	300
230	252	122	0.051	1:30	5275	125
230	253	121	0.050	1:45	5092	185
232	254	121	0.050	2:00	4950	142
232	255	122	0.052	2:15	4825	125
233	255	124	0.055	2:30	4730	95
230	255	123	0.054	2:45	4610	120
228	255	122	0.052	3:00	4520	90
232	256	122	0.051	3:15	4435	85
234	257	122	0.051	3:30	4360	75
235	258	124	0.052	3:45	4295	65
237	258	124	0.052	4:00	4220	75
237	258	123	0.051	4:15	4185	35
237	258	122	0.050	4:30	4115	70
236	258	123	0.051	4:45	4085	30
			FINAL WEIGHT		3760	325

Inlet air temperature = 81°F
Weight of pith = 560 grams
Loss of weight = 12,588 − 3,760 = 8828 grams water
Thickness = 0.91 Inches
Time of drying = 7 hours 18 minutes

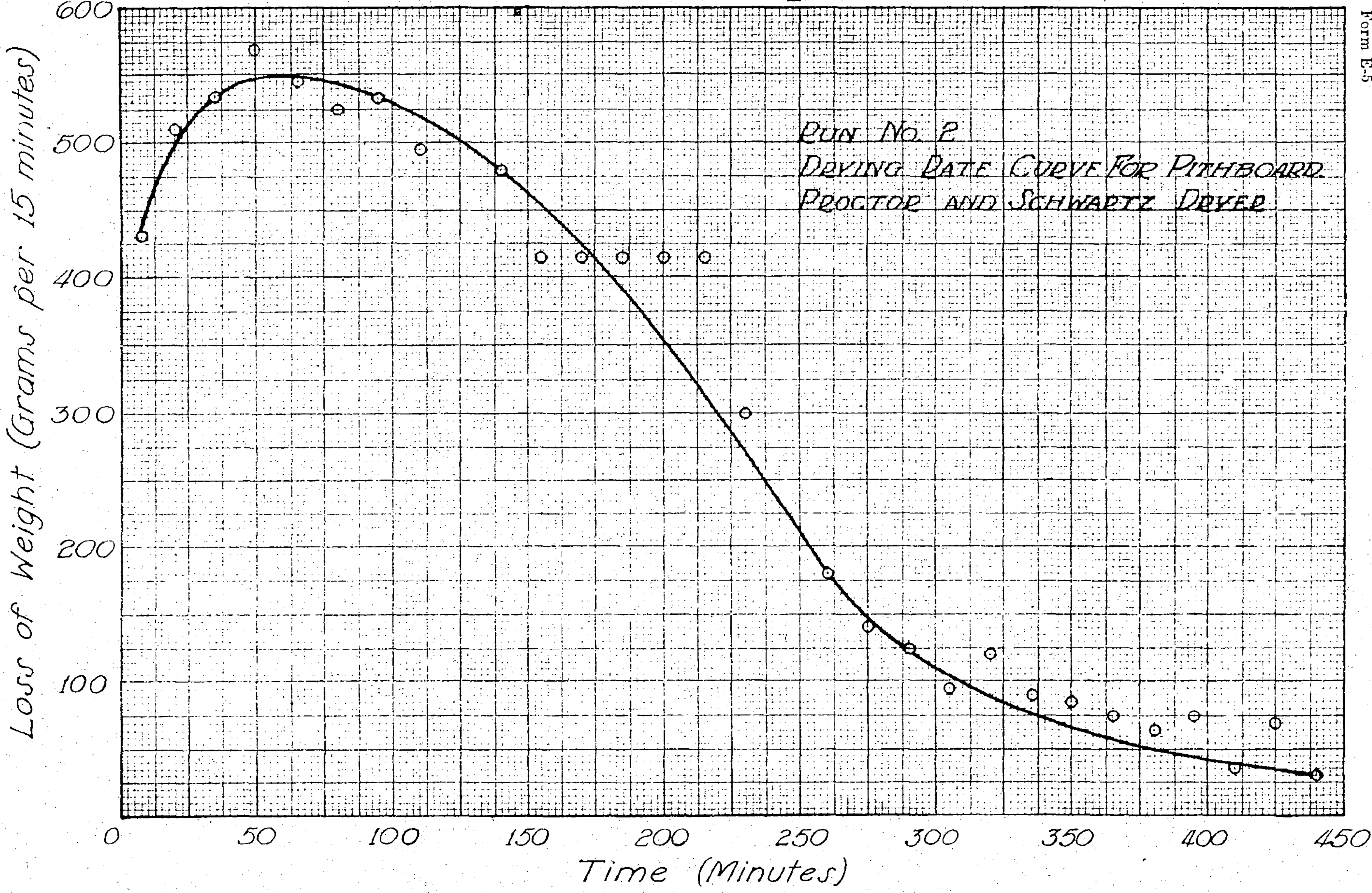
Form E-5



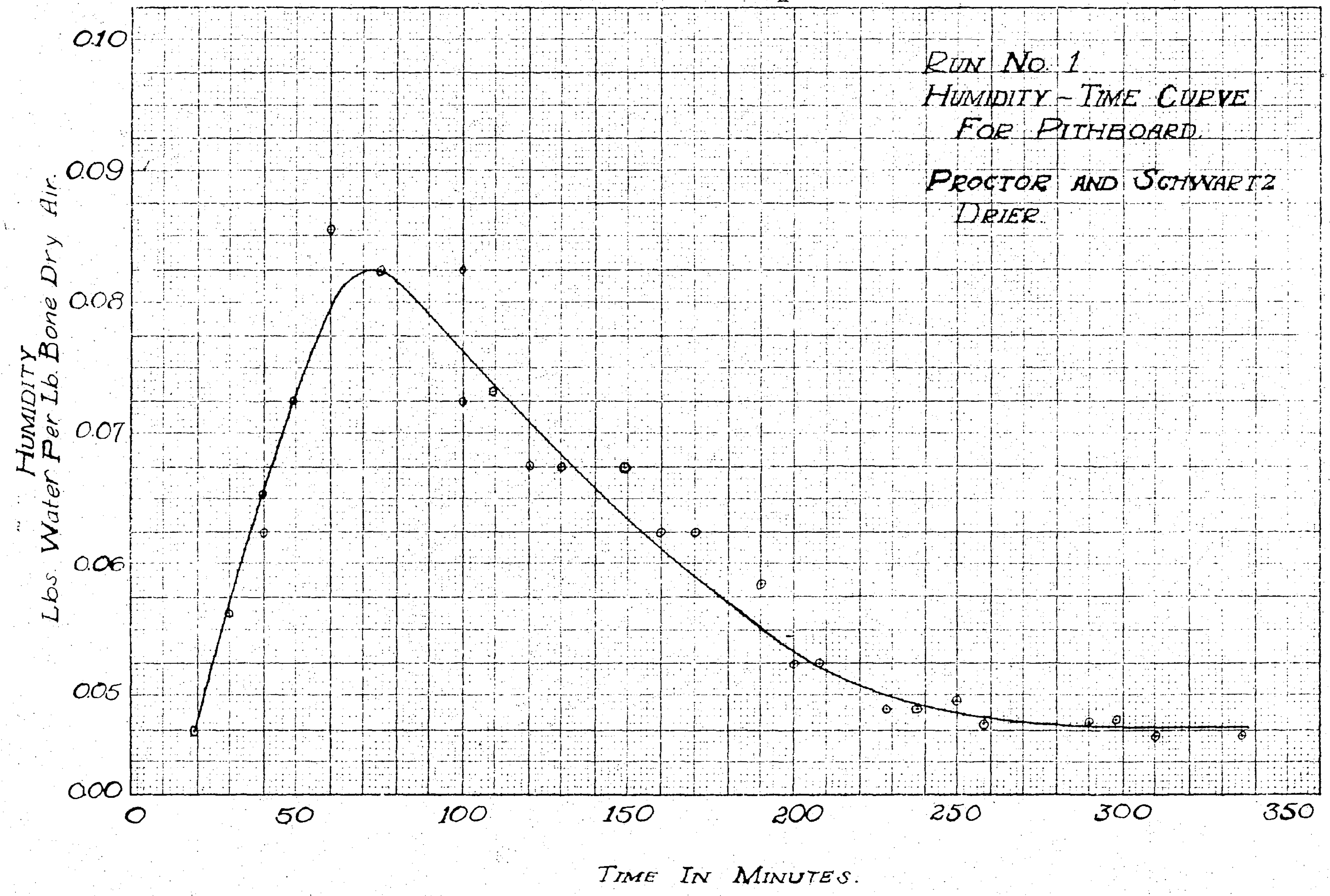
CURVE NO. 5 II
RUN No. 1 ON PITHBOARD
DRYING RATE CURVE
PROCTOR AND SCHWARTZ DRYER
0
50
100
150
200
250
300
350
Time (Minutes)
400
350
300
250
200
150
100
50
0
Loss of Weight (Grams per 10 minutes)

Form E-5

CURVE NO. 7 II



CURVE No. 6II


RUN No. 1
HUMIDITY - TIME CURVE
FOR PITHBOARD.
PROCTOR AND SCHWARTZ
DRIER.
HUMIDITY
Lbs. Water Per Lb. Bone Dry Air.
0.10
0.09
0.08
0.07
0.06
0.05
0.00
0
50
100
150
200
250
300
350
TIME IN MINUTES.

Form E-5

CURVE NO. 8 II

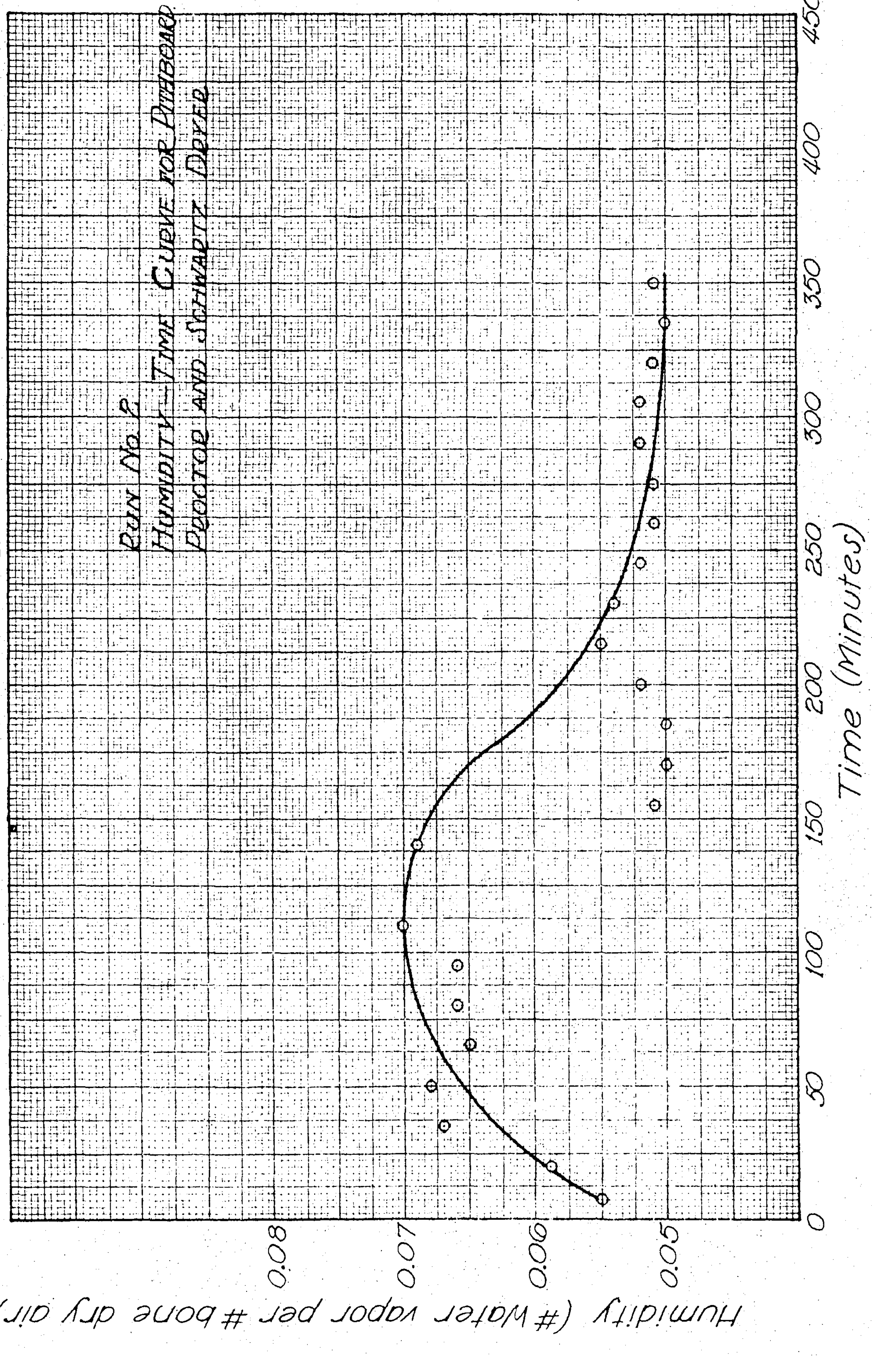


PLATE NO. 6 II

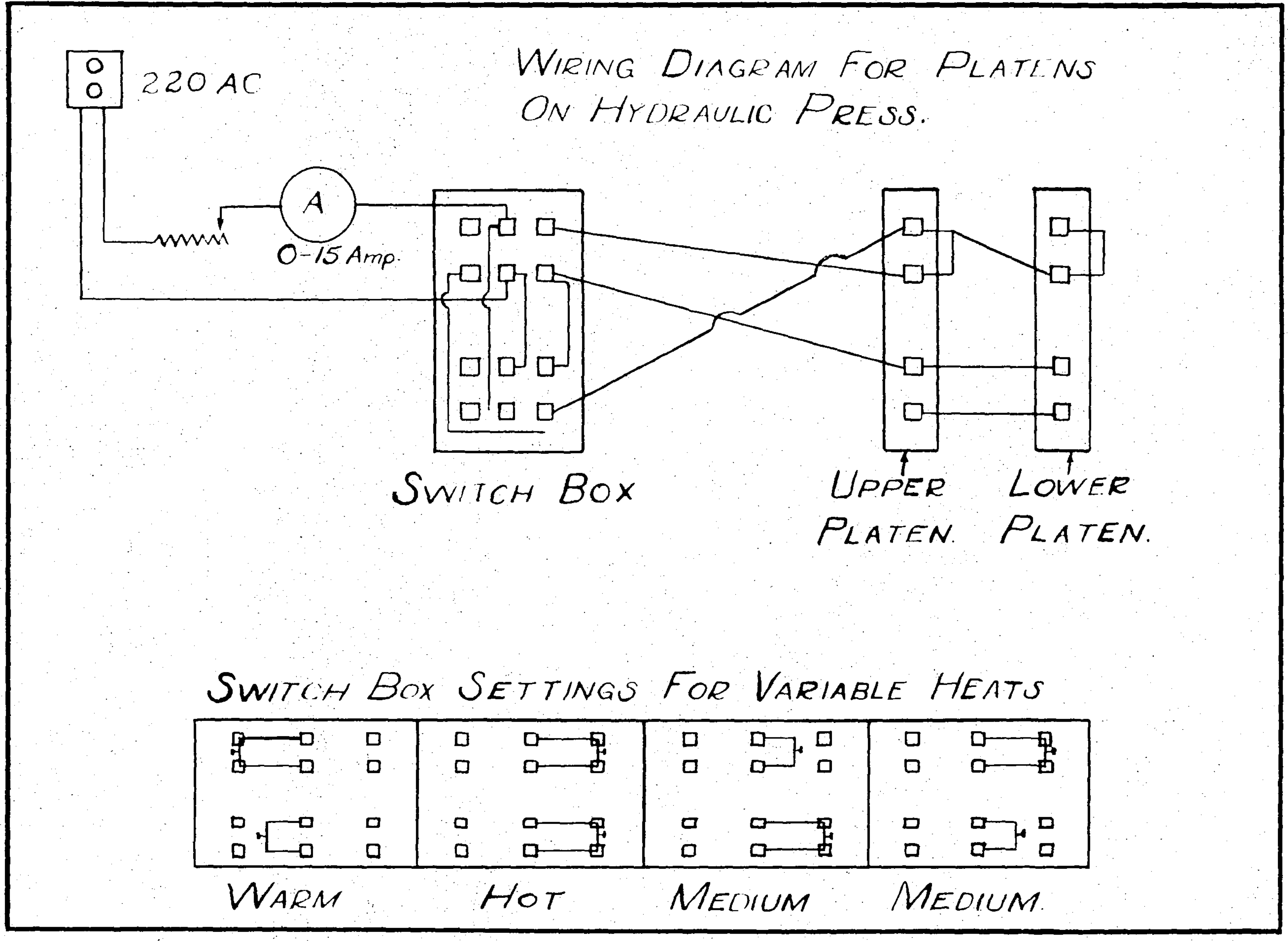

WIRING DIAGRAM FOR PLATENS
ON HYDRAULIC PRESS.
220 AC
A
0-15 Amp.
SWITCH BOX
UPPER
PLATEN.
LOWER
PLATEN.
SWITCH BOX SETTINGS FOR VARIABLE HEATS
WARM
HOT
MEDIUM
MEDIUM.

TABLE NO. 12$_{II}$

CONDUCTIVITY OF REFRIGERATION BOARDS MADE FROM PITH

RUN NO.	PREPARATION	DENSITY	CONDUCTIVITY	DRYING PRESSURE
1	Commercial Cork-board	7.7	.30	
2	Corrugated Box-board		.396	
3	Fiber-Board (Pith removed)	7.65	.42	
4	Beat 1 hour	5.45	.287	.176
5	"	5.88	.29	.1
6	"	4.72	.308	.1
7	Same board treated with alcogel	5.82	.284	
8	Beat 1 hour	5.4	.262	.1
9	" Jordaned	4.78	.288	.1
10	Same board treated with alcogel	5.95	.273	
11	Beat 10 min.; Jordaned	5.49	.29	.394
12	Same board treated with alcogel	6.62	.284	
13	Pith separated by hand; Beat 30 min.	1.87	.249	
14	Beat 30 min.	5.42	.29	.1
15	Beat 15 min.	7.33	.259	.695
16	" Jordaned	4.62	.252	None
17	"	4.28	.256	"
18	"	4.63	.256	"
19	Beat fine and jordaned	6.75	.262	.1
20	Same as above; washed	4.46	.25	.1
21	Beat 15 min.	5.95	.298	.49
22	"	6.16	.292	.92
23	"	6.82	.262	1.95
24	Beat 20 min.	5.45	.294	

alcogel. The contents were steamed in order to dissolve the alcogel, then beaten for one hour in the small beater. The pulp was then placed in iron molds, equipped with fine mesh screen, and allowed to dry in a steam oven. Weights were placed on the molds to prevent the board from warping. The boards were then sanded smoothly and the following tests were made, modulus of rupture, density, moisture absorption, and conductivity. See Table No. 13_{II}, page 108.

Run number six gave the best results. The alcogel did not affect the conductivity. The density was much below that of cork. The moisture absorption for twenty-four hours was reduced to ninety-five per cent.

This study was continued with such materials as NH_4F, asbestos, cornstalk adhesive, NaF, and etc. See results in Table No. 14_{II}, page 110.

e. <u>Fireproofing of pith board</u>

One hundred and fifty grams of air dried pith were placed in a small beater. Four thousand and five hundred cubic centimeters of water were then added. After the pith was well hydrated, the fireproofing binder was added and the contents were beaten for one hour with the roll set rather firmly. The wet pulp was then formed into a board by means of the board forming machine. The board was then placed in a steam oven.

Table No. 13_{II}

EFFECT OF BINDER ON PITH BOARD

Run*	% Alcogel	Density lb/cu ft	Cond'ty	Mod. of rupture	Moisture Absp. ½ hr	Moisture Absp. 24 hrs
1	5	4.21	0.308	486.7	127.6	412.0
2	10	5.40	0.300	-----	40.5	166.5
3	15	4.93	0.294	424.4	226.0	542.0
4	20	5.30	0.272	550.2	89.4	336.5
5	25	5.22	0.330	416.0	76.5	193.0
6	30	5.22	0.292	-----	20.9	95.2
7	40	5.10	0.296	-----	53.3	221.0

*Drying pressure was 0.745 lbs. per sq. in. on all runs

The moisture absorption was run on each sample. As each pith board was held in the flame it was held in such a position that the flame played upon the edges of the sample. See Table No. 14_{II}, page 110.

Samples made up with five per cent cornstalk adhesive gave the lowest moisture absorption for the beater size while the boards painted with Vulrox, an oxidized asphalt, gave the best result for samples which were painted. The samples painted with sodium silicate gave the best fireproofing. None of the samples were absolutely fireproof. The pith board alone could not stand more than three seconds in the flame.

TABLE NO. 14$_{II}$

FIREPROOFING OF PITHBOARD.

NO.	BINDER	DENSITY Lbs/Cu.Ft.	% ABSORPTION		EFFECT OF FLAME		
			$\frac{1}{2}$ HR.	24 HRS.	1 SEC	3 SEC.	8 SEC.
1	5% Na_2SiO_3	4.15	52.4	176.8	Did not burn	Burned rapidly	
2	40% Na_2SiO_3	6.00	66[illegible]	826.0	Burned slowly		
3	50% Na_2SiO_3	4.49	368.0	630.0	Burned rapidly		
4*	Painted Na_2SiO_3	8.44	66.7	440.0	Did not burn	Did not burn	Burned slowly
5	5% NH_4F	5.04	87.1	229.5	Did not burn	Burned rapidly	
6	35% NH_4F	5.21	139.0	414.0	Did not burn	Burned slowly	
7	5% Asbestos	6.33	752.0	811.0	Did not burn	Burned rapidly	
8	40% Asbestos	6.41	736.7	444.0	Burned slowly	Burned rapidly	
9	50% Asbestos	6.52	751.0	805.7	Did not burn	Burned slowly	
10	5% NaF	5.80	368.1	623.0	Did not burn	Burned slowly	
11	20% NaF	5.80	195.1	524.3	Did not burn	Burned rapidly	
12	50% NaF	5.87	566.7	769.0	Did not burn	Burned slowly	
13	Pith only	4.72	131.0	924.0	Did not burn	Burned rapidly	
14	5% Adhesive	4.94	51.3	139.0	Did not burn	Burned rapidly	
15	20% Adhesive	5.02	68.1	435.0	Did not burn	Burned rapidly	
16**	Painted Adhesive	5.70	177.4	356.0	Did not burn	Burned slowly	

TABLE NO. 14 II

FIREPROOFING OF PITHBOARD (Continued)

NO.	BINDER	DENSITY LBS/CU.FT.	% ABSORPTION ½ HR.	% ABSORPTION 24 HRS.	EFFECT OF FLAME 1 SEC.	EFFECT OF FLAME 3 SEC	EFFECT OF FLAME 8 SEC.
17***	Painted Vulrox	22.70	4.9	22.1	Did not burn	Did not burn	Burned slowly
18	5% Marb-L-Cote	4.80	1048.8	1270.0	Burned slowly	Burned rapidly	
19	20% Marb-L-Cote	4.90	67.7	197.8	Burned slowly	Burned rapidly	
20****	Painted Marb-L-Cote	5.10	68.1	435.0	Did not burn	Did not burn	Burned slowly
21	35% Adhesive	5.20	65.7	128.0	Did not burn	Burned rapidly	
22	50% Adhesive	5.80	97.8	233.0	Did not burn	Burned rapidly	

* Best fireproofing of all
** Fourth best
*** Second best
**** Third best

3. Pressboard

a. Methods of preparation

(1). Relation of beating time to strength. A series of mechanical boards was made in which the beating time was varied from zero to fourteen hours. The pulp used had been passed through the rod mill once before beating, then it was washed free of dirt and fines before placing in the beater. The boards were formed on the large suction plate and pressed at one hundred and twenty-one pounds per square inch for two hours with forty to fifty-five pounds steam pressure on the platens. The boards were dried three hours before pressing. See Table No. 1_{III}, page 113.

The modulus of rupture increased with beating to a maximum at twelve hours. This was probably due to higher hydration of the pulp. The maximum density was also at twelve hours beating.

(2). Relation of fiber length to strength. Cooked cornstalks were rod milled rapidly in order to provide long coarse fibers. The fibers were then reduced in length gradually by means of a beater. All pulp was sized three per cent with rosin and five per cent alum. Eight runs were made in this series. See Table No. 2_{III}, page 114.

The boards made in runs one and two were rough and

TABLE 1_{III}

RELATION OF BEATING TIME TO STRENGTH OF PRESSBOARD

Board No.	Beating Time (hours)	Density (Lbs; cu ft)	Modulus of Rupture	Final Moisture Percent
14	0	58.68	3425	3.03
15	1	38.65	5180	5.10
16	2	37.4	7020	6.80
17	3	38.6	4025	5.10
18	4	40.3	3450	5.40
19	5	39.7	4575	6.00
31	7	50.5	4875	1.30
32	8	53.7	5180	2.10
38	9	56.5	7285	3.10
33	10	56.0	— —	4.10
34	12	61.4	8000	6.50
35	14	75.5	6168	2.40

TABLE NO. 2_{III}
RELATION OF FIBER LENGTH TO STRENGTH OF PRESSBOARD.

RUN	PREPARATION OF PULP	MODULUS (LBS./SQ.IN.)	MOISTURE ABSORPTION		REMARKS
			% ½ HR.	% 24 HRS.	
1	No beating	7883	6.47	34.4	Rough board
2	"	7397	9.11	3.50	"
3	Beat 3 min.	7595	6.37	35.0	Good board
4	"	7010	11.4C	40.7	"
5	Beat 5 min.	5397	5.91	30.8	"
6	"	5540	6.16	33.3	"
7	Beat real fine	3520	5.68	36.0	Poor board
8	"	343[illegible]	6.03	33.0	"

shabby looking. Their moduli were the highest of the series but they were undesirable boards. The three minute beating gave good looking boards which were nearly as strong as the first two runs. The pulp which was beaten very fine was worthless, for the strength was lowered greatly.

(3). Relation of rod mill and claflin refining to strength. Cornstalks were passed through the rod mill from one to three times, then claflined various lengths of time. See Table No. 3_{III}, page 116.

The freeness of the pulp showed a close relationship with the strength. Pulps of the same freeness varied widely due to differences in fiber length. The strength of the boards varied also due to unavoidable irregularities in pressing. Two times through the rod mill and twenty minutes of claflining gave the best results for mechanical boards.

(4). Relation of freeness to strength. The next series of runs was made by using pulp that had been passed through the rod mill twice. The pulp was claflined for different lengths of time in order to determine the maximum time for the strongest board. See Table No. 4_{III}, page 117.

As before, a freeness of twelve seconds produced the strongest board. The strength of the board was lowered by increasing the refining. The board crushed badly after too

TABLE NO. 3_{III}

EFFECT OF ROD MILL AND CLAFLIN ON STRENGTH OF PRESSBOARD.

RUN	TIMES THROUGH RODMILL	TIME IN CLAFLIN	FREENESS (SECONDS)	MODULUS Lbs/Sq In.
1	1	20	8	1725
2	1	20	8	1895
3	1	20	8	1630
4	1	20	8	1923
5	1	20	8	2007
6	2	20	12	5840
7	2	20	12	5100
8	2	20	12	6745
9	2	20	12	7560
10	2	20	12	7750
11	3	5	4	2928
12	3	5	4	3942
13	3	5	4	4500
14	3	5	4	5680
15	3	5	4	5200
16	4	3	6	3600
17	4	3	6	4520
18	4	3	6	3900
19	4	3	6	7000
20	4	3	6	6800

TABLE NO. 4III

RELATION OF FREENESS OF PULP TO STRENGTH OF PRESSBOARD

No.	Time in Claflin (Minutes)	Freeness (Seconds)	Modulus of Rupture (Lbs/sq.in.)
115	10	3	1784
116	10	3	2562
117	10	3	1922
118	10	3	2264
119	10	3	2495
120	10	3	2180
121	10	3	2280
156	5	4.7	2040
157	5	4.7	2757
158	5	4.7	1887
159	5	4.7	1983
132	5	5	2044
133	5	5	2937
134	5	5	2500
137	5	5	2937
138	5	5	3002
140	5	5	3353
141	5	5	1956
147	$12\frac{1}{2}$	6	2939
148	$12\frac{1}{2}$	6	3457
149	$12\frac{1}{2}$	6	2155
150	$12\frac{1}{2}$	6	2545
151	$12\frac{1}{2}$	6	2897
96	20	12	5100
97	20	12	7750
98	20	12	7500
99	20	12	7700
100	15	8	3950

TABLE NO. 4$_{III}$

RELATION OF FREENESS OF PULP TO STRENGTH OF PRESSBOARD (CONT.)

NO.	TIME IN CLAFLIN (MINUTES)	FREENESS (SECONDS)	MODULUS OF RUPTURE (LBS./SQ.IN.)
101	15	8	4220
102	15	8	4450
103	17$\frac{1}{2}$	10.1	5240
104	17$\frac{1}{2}$	10.1	5650
105	17$\frac{1}{2}$	10.1	5320
106	22$\frac{1}{2}$	14.2	5160
107	22$\frac{1}{2}$	14.2	5520
108	22$\frac{1}{2}$	14.2	5430

long a refining.

A similar study was made on cooked stalks. One pass through the rod mill gave the best results. The pulp was then claflined for various lengths of time. The freeness was not determined. See Table No. 6_{III}, page 120.

A strong board required from five to six minutes refining. Too much refining was harmful. The first few runs were weak due to the fact that the fibers were not reduced enough in length to form a good mat.

(5). Effects of fermentation on pressboard. Reece (38) completed some interesting work on fermented pulp. See Table No. 7_{III}, page 121. Mechanical pulp that was fermented for twenty days produced a stronger board than pulp which was not fermented. The author repeated the above test using cooked pulp. Fermentation increased the strength of the board.

(6). Effect of method of drying on strength of the finished board.

(a). Preliminary drying of the mat. Previous experiments seemed to show the fact that all mats should contain at least fifteen per cent moisture when pressed. No mention was made of the higher limit. A series of runs was made in order to determine the optimum per cent.

Cornstalks were passed through the rod mill and then

TABLE NO. 5III

RELATION OF MOISTURE TO STRENGTH OF PRESSBOARD.

RUN NO.	% MOISTURE IN BOARD WHEN PRESSED	MODULUS OF RUPTURE	DENSITY LBS./CU. IN	TIME IN OVEN (MIN)
72	67.5	4400	50.9	None
73	67.4	4000	49.8	None
74	66.85	3150	47.0	15
75	66.6	3000	46.8	30
76	63.5	2750	43.7	30
77	62.9	2600	42.1	30
78	60.0	2100	41.0	45
79	59.2	2000	41.2	45
80	57.3	1900	40.0	60
81	57.5	1950	40.5	60
82	45.2	1750	40.5	90
83	27.0	1520	36.0	120
84	19.0	1422	38.0	150
85	12.0	1323	39.0	180
86	0	1000	40.0	210

TABLE NO. 6III

EFFECT OF TIME IN CLAFLIN ON STRENGTH OF PRESSBOARD

RUN NO.	TIME IN CLAFLIN (MINUTES)	MODULUS OF RUPTURE	RUN NO.	TIME IN CLAFLIN (MINUTES)	MODULUS OF RUPTURE
210	2	5520	218	5	7830
211	2	5420	219	6	9151
212	2	5660	220	6	8562
213	3	6630	221	6	8930
214	3	7240	222	7	8400
215	3	7520	223	7	7900
216	5	8010	224	7	8120
217	5	7610			

TABLE NO. 7_{III}

EFFECT OF FERMENTATION OF PULP ON PRESSBOARD

Fermentation (Day)	% Rosin	Modulus of Rupture	H_2O Absorption % Gain ½ hr.	H_2O Absorption % Gain 24 hrs.
0	0	4000	74.1	120.0
20	0	4280	46.2	94.4
0	5	4310	14.5	57.5
20	5	4360	9.4	33.3
0	5★	4070	11.3	49.4
20	5ǂ	4825	9.1	25.6

Note: All boards pressed at 600 lbs/sq. in.
★Alum added to pH of 4.3
ǂ " " " " " 4.4

TABLE NO. 8_{III}

EFFECT OF VARYING DRYING PRESSURE ON STRENGTH OF PRESSBOARD

Pressure Lbs/sq. in.	Modulus of Rupture
346*	3700
520	4700
695	4520
870	4650

*1 Hour in Press.
Temperature 130° C.

beaten for eight hours. The pulp was sucked dry on the small suction plate. The mat was placed in an iron mold and subjected to pressure. The boards were then placed in the Coe dryer and dried at one-half hour intervals up to complete dryness, then they were pressed one hour, the platens being heated during this process. See Table No. 5_{III}, page 120.

Run number seventy-two gave the strongest board while run number eighty-six gave the weakest board. The strongest boards were produced from mats containing sixty-six per cent or more moisture.

(b). Preliminary pressing of the mat. Samples of cooked pulp were pressed at different pressures in order to determine the amount of moisture that could be removed without drying. The pulp was cooked three hours, rod milled once and claflined five minutes. See Table No. 9_{III}, page 123.

(c). Relation of drying time to strength of finished board. Hartford (16) reported the optimum drying time to be at least equal to seventy-five minutes. See Table No. 11_{III}, page 124.

A series of boards were made in order to check the above results. The pulp was rod milled once and beaten four hours in the beater. The boards were then pressed at different lengths of time. See Table No. 12_{III}, page 125.

TABLE NO. 9 III

MOISTURE REMOVAL FROM PRESSBOARD AT VARIOUS TEMPERATURES.

RUN NO.	WT. BEFORE PRESSING	WT. AFTER PRESSING	WT. AFTER DRYING	% MOISTURE OF ORIGINAL	% MOISTURE AFTER PRESSING	PRESSURE USED	DENSITY LBS/CU. FT.
1	362.0	287.0	93	74.3	67.6	44.3	24.8
2	370.0	274.0	93.3	74.5	68.2	88.5	26.1
3	402.0	268.5	96.2	75.8	64.3	132.8	28.1
4	407.0	292.1	97.0	76.3	66.5	177.0	25.7
5	410.0	272.6	94.8	76.5	65.2	221.3	25.3
6	400.0	259.3	91.0	77.5	65.0	265.5	25.5
7	341.0	245.4	89.0	73.7	63.9	309.8	28.1
8	350.0	242.6	90.7	73.9	62.5	354.0	28.4
9	365.0	223.5	86.0	76.5	61.8	398.3	28.1
10	372.0	228.4	87.1	76.5	62.0	442.5	27.9
11	423.0	242.3	96.9	77.0	60.0	555.0	30.5
12	428.0	240.0	98.8	76.9	59.0	663.8	30.0
13	335.0	207.2	87.9	75.0	57.8	575.3	31.0
14	335.0	266.7	87.0	74.0	67.2	44.3	22.6
15	351.5	275.5	92.9	73.9	66.5	88.5	24.2
16	388.0	270.7	92.0	76.2	66.0	132.8	23.6
17	395.0	265.5	93.6	76.2	64.9	177.0	22.9
18	432.5	268.5	97.0	77.5	63.8	221.3	27.4
19	446.0	275.8	101.3	77.3	63.5	265.5	25.7
20	477.0	312.0	116.8	76.5	62.6	309.8	26.6
21	471.0	303.0	114.2	75.8	62.5	354.0	27.3
22	393.0	273.0	105.7	73.2	61.5	398.3	29.7
23	428.5	251.2	99.9	76.9	60.4	442.5	27.5
24	383.0	227.5	93.9	75.5	59.2	555.8	28.4
25	387.0	224.3	93.1	75.7	58.5	663.8	30.5
26	345.5	200.0	91.0	74.0	54.5	874.4	32.0

TABLE NO. 10 III

EFFECT OF VARYING DRYING PRESSURE ON PRESSBOARD

Pressure Lbs./sq. in.	Modulus of Rupture	H_2O Absorption	
		% Gain ½ hr.	% Gain 24 hrs.
0	390	20.5	80.7
367	3427	68.0	126.8
440	3834	79.9	133.2
550	4317	*68.8	124.2
600	4000	68.0	118.0
733	3247	67.2	116.7
1100	3300	92.2	121.0
2200	2967	98.2	130.1
3000	2975	74.1	113.0

TABLE NO. 11 III

EFFECT OF VARYING TIME OF PRESSING ON STRENGTH OF PRESSBOARD

Time in Minutes	Modulus of Rupture
15	920
30	880*
45	3000
60	3650
75	3950

Note:
Pressure, 550 lbs./sq. in.
Temperature, 130° C.
*Press not working correctly.

TABLE NO. 12 III

EFFECT OF VARYING TIME OF PRESSING ON STRENGTH OF PRESSBOARD

RUN I

BOARD NO.	TIME DRIED	MODULUS OF RUPTURE
1	30	1630
2	30	1652
3	30	1672
4	30	1885
5	30	1898
6	30	2007
7	60	1710
8	60	1795
RUN II		
9	30	2939
10	30	2897
11	30	3457
12	60	2155
13	60	2545
RUN III		
14	30	5658
15	30	5166
16	45	1694
17	45	4748
18	45	5987
19	60	4438
20	60	4083
21	60	3943

Thirty minutes gave the best drying time. Some good boards were made by drying only twenty minutes.

(d). Relation of drying pressure to strength of finished board. Reece (35) studied the effect of various pressures on the strength of pressboard. He reported the maximum strength at a pressure of five hundred and fifty pounds per square inch. See Table No. 10_{III}, page 124.

Hartford reported a maximum strength at five hundred and twenty pounds per square inch. See Table No. 8_{III}, page 121.

Results obtained from this series showed the maximum strength between four hundred and seventy-five and five hundred and thirty. See Table No. 13_{III}, page 127.

(e). Effect of various temperatures, during pressing, on strength. A series of runs was made in order to determine the effect various temperatures have on the strength. The pulp was prepared by cooking one bale of cornstalks with water for three hours at one hundred and forty degrees Centigrade, then rod milled rapidly, and claflined for six minutes. Mats were formed by means of the small suction box. While the press was cold, mats were inserted into the press. Steam was turned on at the same time that the boards were pressed. Then mats were inserted into the press while it was hot. See Table No. 14_{III}, page 128.

TABLE NO. 13 III

EFFECT OF VARIOUS PRESSURES ON STRENGTH OF PRESSBOARD

RUN	POUNDS PER SQ IN	MODULUS LBS/SQIN	DENSITY LBS/CUFT	% MOISTURE	MOISTURE ABSORPTION	
					% ½ HR.	% 24 HRS.
1	795	6800	63.1	73.0	8.2	42.1
2	795	5990	63.4	73.0	6.3	34.5
3	795	5300	64.5	73.0	5.5	36.8
4	706	6900	67.5	74.5	7.7	45.1
5	706	7490	71.2	74.5	7.8	40.6
6	706	6780	63.7	74.5	8.0	42.5
7	618	6970	65.7	74.0	9.7	42.5
8	618	6720	65.8	74.0	9.1	40.7
9	618	6800	63.0	74.0	11.2	46.4
10	530	7350	66.6	74.0	9.0	41.0
11	530	7390	65.8	74.0	8.3	36.5
12	530	6930	64.0	74.0	9.2	45.0
13	441	7600	64.6	74.0	8.9	42.6
14	441	7400	61.5	74.0	9.3	42.5
15	441	7500	57.7	74.0	7.3	35.9
16	353	6500	58.1	73.5	7.2	40.8
17	353	6310	57.3	73.5	6.1	37.2
18	353	6000	56.0	73.5	7.4	38.0

TABLE NO. 14 III

EFFECT OF PRESSING AT VARIOUS TEMPERATURES ON STRENGTH OF PRESSBOARD

NO.	MODULUS LBS/SQ IN.	DENSITY LBS/CU FT.	MOISTURE ABSORPTION ½ HR.	MOISTURE ABSORPTION 24 HR.	MOISTURE CONTENT %	METHOD OF PRESSING
1	7050	67.5	9.80	43.5	74.0	Cold
2	7300	64.0	7.40	35.6	74.0	"
3	6900	68.0	9.00	42.3	74.0	"
4	7100	68.2	5.30	36.4	74.0	"
5	7600	66.5	5.30	35.1	74.0	"
6	8000	60.0	4.20	30.3	74.0	"
7	6500	62.0	7.50	44.0	74.5	Hot
8	5550	58.0	6.10	39.6	74.5	"
9	6000	55.6	5.30	36.4	74.5	"
10	5800	60.0	10.40	42.1	71.5	"
11	6000	59.0	7.90	37.8	71.5	"
12	5800	53.4	8.20	39.6	71.5	"
13	5630	63.5	8.50	43.5	73.5	"
14	6730	66.8	7.60	46.7	73.5	"
15	6050	64.0	8.30	45.6	73.5	"
16	6600	65.4	6.50	37.4	73.0	"
17	6470	66.0	5.60	36.6	73.0	"
18	6570	66.3	5.50	35.8	73.0	"
19	7150	68.3	8.50	38.6	72.2	Cold
20	7200	67.3	7.70	41.8	72.2	"
21	6975	61.5	13.10	47.6	72.2	"
22	8400	69.0	5.20	32.1	74.5	"
23	7100	70.2	5.80	30.0	74.5	"
24	7600	66.6	5.10	33.0	74.5	"
25	7150	64.7	5.95	31.8	71.5	"
26	6700	72.3	5.75	33.7	71.5	"
27	6800	72.3	5.75	29.3	71.5	"
28	6400	67.0	5.92	32.2	74.0	Hot
29	6950	69.4	5.56	31.1	74.0	"
30	7200	66.4	5.92	33.7	74.0	"
31	6050	69.5	6.72	32.8	74.0	"
32	6600	67.0	6.15	36.1	74.0	"
33	6500	66.1	6.59	33.2	74.0	"

The average modulus of rupture for the boards inserted into the cold press was 6970 pounds per square inch while the average modulus for the mats inserted into the hot press was 6130. Temperature did not seem to affect the strength a great deal.

b. <u>Sizing of pressboard</u>

(1). Beater sizing. The pulp used for all of the following tests was prepared by cooking the cornstalks for three hours at a pressure of forty-five pounds per square inch. These stalks were then rod milled once and claflined from five to six minutes. The mat was formed on the insulation wall board forming machine, then lapped, and placed in an air-tight box.

Enough of the above pulp was weighed out to secure one pound of dry fiber and placed into a small one pound beater to which twenty-five pounds of water were added. The contents were circulated ten minutes before the sizing was added.

The temperature of the pulp was held at sixty-five to sixty-eight degrees centigrade. The size was added to the beater and allowed to circulate for an additional ten minutes. The hydrogen ion concentration was adjusted to four and five-tenths to four and seven-tenths by the addition of alum.

Mats were formed in the small suction box, then pressed in a small hydraulic press, equipped with electric platens.

All boards were pressed at four hundred pounds per square inch. Each platen was equipped with a thermometer well. The temperature was regulated, by means of a rheostat to a temperature between 130° and 140° Centigrade.

The average drying time was from thirty to forty minutes. The longer fibers required a shorter time of drying while the finer pulp required a longer time. The temperature was used as an indicator for determining the time to remove the board from the press.

Each board was tested for modulus of rupture and moisture absorption for one-half and twenty-four hours.

(a). Rosin and alum. This series of runs was made in order to determine the effect that preparation of pulp has on waterproofing. When size was added three per cent of rosin was used. The analysis of the rosin size used was furnished by the Paper Maker's Chemical Corporation, Milwaukee, Wisconsin. See Table No. 18_{III}, page 131. See Table No. 15_{III}, page 132, for results of this series.

The boards were not sized correctly in any case. This was probably due to the fact that there was not enough alum present to precipitate the rosin. The Masonite pressboard absorbed thirty-one and eight-tenths per cent water in twenty-four hours. Pulp that was cooked a longer time seemed to give the best waterproofing.

TABLE NO. III 18

REPRESENTATIVE ANALYSIS OF ROSIN SIZE USED IN WALLBOARD MANUFACTURE

Moisture	39.01%
Total Alkali (as Na_2O)	4.25%
Free Alkali (as Na_2CO_3)	0.44%
Free Rosin	27.70%
Combined Rosin	24.25%

TABLE NO. 19 III

SIZING PRESSBOARD WITH SODIUM ALGINATE.

VARYING PRECIPITANTS USED	I		II	
	WATER ABSORPTION		WATER ABSORPTION	
	½ HOUR	24 HOURS	½ HOUR	24 HOURS
$CuSO_4 \cdot 5H_2O$	15.15	61.23	11.37	50.60
$FeSO_4 \cdot 7H_2O$	12.81	61.22	12.26	41.66
$Fe_2(SO_4)_3 \cdot 9H_2O$	22.93	70.13	14.66	37.19
$Al_2(SO_4)_3 \cdot 24H_2O$	13.15	66.40	13.60	44.33
Blank	14.37	65.43	30.60	65.57

Run I: 3 Hr. Water cook, 140°C, 400# per sq. in. pH 4.5–4.6. Distilled water used.

Run II: Same procedure as above except tap water was used.

TABLE NO. 15III

WATERPROOFING OF PRESSBOARD

No.	Preparation of Pulp	pH	% Rosin	% Alum	H_2O Absorption % Gain $\frac{1}{2}$ hr.	% Gain 24 hrs.
1	3 hr. H_2O Cook	4.7	3	3	84.7	148.0
2	"	4.7	3	3	77.8	110.8
3	"	4.7	3	3	85.3	139.2
4	48 hr. H_2O Cook		0	0	62.7	94.7
5	"		0	0	110.0	129.3
6	"		0	0	65.4	86.0
7	Mechanical	4.7	3	3	57.0	116.0
8	"	4.7	3	3	67.0	110.0
9	"	4.7	3	3	53.4	87.0
10	"	5.2	0	0	108.0	132.0
11	"		0	0	92.2	114.0
12	"		0	0	106.0	129.5
13	Masonite Pressboard				6.7	31.8

The next series of runs was made in order to discover the optimum per cent of rosin and alum to use. The per cent alum was held constant while the per cent rosin was varied. See Table No. 16_{III}, page 134.

The best range of sizing seemed to be between a ratio of 0.6 to 1.0, that is, six-tenths as much rosin as alum. Too high a per cent rosin injured the strength of the board.

(b). Paraffin and alum. A paraffin emulsion was precipitated with alum. The emulsifying agents used were tri-ethanolamine and stearic acid. See Table No. 17_{III}, page 135.

(c). Sodium alginate. A series of studies was made on sodium alginate or Kelco bond. Two per cent of this size was used. It was precipitated with various divalent and trivalent salts. Two runs were made with each precipitating agent, one with tap water and the other with distilled water. Three per cent alum, four and one-half per cent copper sulphate, four and one-half per cent ferrous sulphate and two per cent ferric sulphate were used to precipitate the Kelco bond for the first series while a smaller amount was used for the second series. See Table No. 19_{III}, page 131.

Tap water gave the best boards of the series. This was probably due to the fact that tap water contains salts which help precipitate the size. The trivalent iron sulphate gave

TABLE NO. 16 III

SIZING OF PRESSBOARD WITH ROSIN AND ALUM.

No.	Thickness	% Rosin	% Alum	pH	Modulus Lbs/Sq. In.	H_2O Absorption % Gain ½ hr	H_2O Absorption % Gain 24 hrs.
1	.157	3	7	4.6	6645	8.15	43.7
2	.164	3½	5	4.4	7670	8.50	41.4
3	.160	4	7½	4.4	7203	6.00	34.5
4	.130	4½	7	4.2	8168	5.54	31.8
5	.171	5	7½	4.4	5567	6.90	27.4
6	.153	5½	7	4.4	8151	6.19	35.8
7	.140	6	7	4.3	8466	4.90	29.4
8	.140	6½	7	4.3	7941	5.49	31.9
9	.143	7	7	4.3	7696	5.75	28.7
10	.142	7½	7	4.3	6775	6.36	32.5
11	.169	8	7	4.3	5484	6.42	29.3

TABLE NO. 17 III

PRESSBOARD SIZE RUNS ALUM AND PARAFFIN

Pulp Preparation	Sizing	pH	H_2O Absorption	
			% Gain ½ hr.	% Gain 24 hrs.
Cooked 3 hrs. Rodmilled; Claflined	.5% Alum 3% Paraffin	4.5	3.4	27.1
"	"	4.6	3.6	22.3
"	"	4.6	4.3	25.0
"	"	4.6	5.3	24.3
"	"	4.5	4.2	25.2
"	"	4.5	56.4	92.9
"	"	4.5	60.5	92.0
"	"	4.5	5.4	19.6
"	"	4.5	66.8	94.4
"	"	4.5	4.2	23.7

the best waterproofing.

The next series of boards was made in order to compare the sizing qualities of Kelco bond with paraffin size. See Table No. 20_{III}, page 137. Kelco bond did not weaken the board as much as the paraffin size, but paraffin gave better waterproofing.

Kelco bond was then compared with rosin. See Table No. 21_{III}, page 138. As before, the sodium alginate failed to waterproof the board as well as the standard sizes.

(d). Studies on prepared emulsions. Paraffin, asphalt, and pitch were used as sizing agents. Since these sizes were not soluble in water, it was necessary to secure a suitable emulsifying agent. See Table No. 22_{III}, page 139.

Asphalt was used as a sizing material for the first fifteen runs. Stearic acid and tri-ethanolamine were the emulsifying agents for the first seven runs. Rosin and tri-ethanolamine were the emulsifying agents for the next five runs. Rosin and soap were the agents used to precipitate the size for the last three runs of this series. Very little difference was found in the effect of the emulsifying agents because the absorption in the first two cases was approximately the same. The absorption was higher for the group three in this first series. The melting point of the asphalt seemed to make little difference in the absorption value.

TABLE NO. 20_{III}

STUDIES ON SIZING PRESSBOARD WITH SODIUM ALGINATE.

Run No.	Sizing	pH	Modulus Lbs./Sq. In.	H_2O Absorption	
				% Gain ½ hr.	% Gain 24 hrs.
I	3% Kelco 6½% $CuSO_4$	4.6	8960	18.8	75.7
II	3% Kelco 5½% $FeSO_4$	4.6	8173	13.9	56.8
III	3% Kelco 4% Alum	4.7	8827	15.7	59.0
IV	Blank		7750	10.7	40.1
V	3% Paraffin 3% Alum	4.6	5712	6.2	23.8
VI	"	4.6	4400	5.4	19.6

All boards pressed at 400#/sq. in.
Temperature 140° C.
Drying time 65 min.

TABLE NO. 21 III

PRESSBOARD SIZE RUNS No. 500

Kind of Size	Am't of Alum	pH	Drying Time	Strength	H_2O Absorption %Gain ½ hr.	%Gain 24 hrs.
Alum Kelco Bond	6%	4.6	45 min.	2579	46.4	77.8
"	6%	4.6	60 "	3278	39.5	72.8
"	6%	4.1	55 "	2700	46.2	75.2
"	5½%	4.5	65 "	2317	45.1	71.2
"	5½%	4.55	35 "	2631	57.1	80.2
"	5½%	4.5	40 "	2316	51.1	75.3
Alum Rosin		4.6	40 "	1351	9.75	49.05
"	6%	4.65		1483	7.45	44.8
"	6%	4.6		1845	8.5	41.8
"	6%	4.55		1813	7.5	42.5
"	6%	4.6			8.65	44.0

Pulp Preparation: 3 hr water cook; Rodmilled once; Washed once; Claflin 18 min; Formed on Sweeney Board Machine; Not dried; Kept in constant humidity until repulped in 1# beater.

$Al_2(SO_4)_3$ added before regular size.

Pressed and dried at 400#; 140°

TABLE NO. 22 III

PRESSBOARD SIZING RUNS

No.	M.P. °F	Emulsifying Agent	pH	% Rosin	% Alum	H_2O Absorption	
						%Gain ½ hr.	%Gain 24 hrs.
1	127	S.A.-T.E.A.	5.0	0	3	6.5	27.1
2	127	"	5.0	0	4	6.8	24.4
3	147	"	5.2	0	3	10.5	36.0
4	242	"	5.2	0	4	6.6	32.9
5	242	"	5.3	0	3	8.2	23.9
6	High M.P.	"	4.6	0	4	5.3	26.8
7	"	"	4.6	0	4	6.2	26.7
8	127	Rosin-T.E.A.	4.3	4	4	6.9	28.2
9	127	"	4.2	4	4	6.9	25.0
10	147	"	5.2	4	4	5.6	32.3
11	147	"	5.2	4	4	6.9	31.9
12	Low M.P.	"	4.2	4	4	6.5	26.1
13	"	Rosin-Soap	5.2	4	4	6.6	32.9
14	242	"	4.6	4	4	9.5	47.4
15	242	"	4.6	4	4	6.4	32.2
16	High M.P.	T.E.A. Soap	4.2	4	4	6.5	21.1
17	"	Soap-S.A.-T.E.A.	4.0	0	5	7.2	33.5
18	"	"	4.0	0	5	18.4	45.2
19	127	O.A.-T.E.A.	4.2	0	5	9.7	43.6
20	127	"	4.2	0	5	9.3	39.4
21		S.A.-T.E.A.					
1		O.A.-T.E.A.	4.9	0	4	6.0	26.0
2		"	4.9	0	4	4.9	27.2
3		S.A.-T.E.A.	4.5	0	4	7.4	23.2
4		"	4.5	0	4	6.3	27.9

TABLE NO. 22 III

PRESSBOARD SIZING RUNS (continued)

No.	MP °F	Emulsifying Agent	pH	% Rosin	% Alum	H_2O Absorption	
						% Gain ½ hr	% Gain 4 hrs
5		SA-TEA	4.7	0	4	8.8	46.[illegible]
6		"	4.1	3	3	9.3	36.9
7		"	4.1	3	3	8.0	32.0
8		"	5.4	3	3	5.7	25.7
9		"	5.4	3	3	9.7	34.7
10		"	4.1	5	5	7.3	33.1

O.A. = Oleic Acid
T.E.A. = Triethanolamine
S.A. = Stearic Acid

1-15 = Asphalt
16-18 = Pitch
19-20 = Asphalt
21 = Asphalt Paraffin
1-10 = Paraffin

Pitch was used as the sizing agent for the series of runs from sixteen to eighteen. Tri-ethanolamine and soap were used as the emulsifying agent while rosin and pitch were the sizing agents. This produced the lowest absorption value for the entire series. The absorption was high for the seventeenth and eighteenth runs. Soap, stearic acid and tri-ethanolamine were used as the emulsifying agents.

Paraffin was used as the sizing material for the last ten runs. The first two runs of this series were sized very well. Stearic acid and tri-ethanolamine did not produce as low absorption values as oleic acid and tri-ethanolamine.

(e). Commercially prepared emulsions. This series of runs was made on commercially prepared emulsions. Three grades of Bennett's prepared rosin-paraffin size were used. Two grades of Barber's asphalt emulsion were used for the last series of runs. See Table No. 24_{III}, page 142.

Good absorption values were received from these studies but in most every case the strength was injured decidedly. The hard asphalt injured the strength the least but it was of very little value as a moisture proofing material. Bennett size No.5 gave the best sizing results in the whole series. Six per cent size produced a board with an absorption of twenty-four per cent. The moludus was 5300 pounds per square inch.

TABLE NO. 24 III

EFFECT OF COMMERCIALLY PREPARED EMULSIONS ON PRESSBOARD

Board No.	Size		Load in Grams	Modulus Lbs/Sq In.	H_2O Absorption	
	Kind	%			% Gain ½ hr.	% Gain 24 hrs.
16-1	B-5	2	2150	4600	3.7	18.6
16-2	B-5	2	1625	4600	4.8	21.1
17-1	B-5	4	1493	4800	5.2	34.7
17-2	B-5	4	2015	5310	4.7	37.4
18-1	B-5	6	1596	4950	6.8	25.2
18-2	B-5	6	2250	5550	7.1	24.3
2-1	B-5	10	1174	3160	3.7	22.8
2-2	B-5	10	1030	4037	2.8	21.4
4-1	B-5	20	996	3500	5.2	20.4
4-2	B-5	20	669	3090	5.2	20.4
5-1	B-5	30	1196	3260	4.8	15.5
5-2	B-5	30	1192	3150	5.3	15.5
8-1	B-18	2	1425	4400	9.1	31.1
8-2	B-18	2	1414	3950	6.7	31.0
9-1	B-18	4	1270	4060	7.3	26.6
9-2	B-18	4	1930	4160	5.2	20.9
10-1	B-18	6	1023	3600	8.8	27.9
10-2	B-18	6	1080	3200	5.2	25.5
6-1	B-18	10	1041	3100	4.8	21.3
6-2	B-18	10	1460	3575	5.3	23.1
7-1	B-18	20	1025	3070	6.6	25.3
7-2	B-18	20	785	3000	6.0	23.7
11-1	B-1	2	2170	5850	4.4	23.1
11-2	B-1	2	2156	6000	4.4	23.1
12-1	B-1	4	1389	4512	6.5	23.9

TABLE NO. 24III

EFFECT OF COMMERCIALLY PREPARED EMULSIONS ON PRESSBOARD (CONT)

Board No	Size		Load in Grams	Modulus LBS/SQ IN.	H_2O Absorption	
	Kind	%			% Gain ½ hr	% Gain 24 hrs
12-2	B-1	4	1700	4340	5.7	22.6
13-1	B-1	6	1335	3860	3.9	19.8
13-2	B-1	6	1489	4025	5.1	23.3
14-1	B-1	10	1455	4000	3.9	17.0
14-2	B-1	10	1725	3950	4.2	17.7
15-1	—	—	2300	7500	25.3	58.6
15-2	—	—	2300	7500	30.4	63.2
19-1	R	2	1935	5800	7.7	38.5
19-2	R	2	1872	6050	8.2	36.6
20-1	R	4	1749	6200	8.5	46.6
20-2	R	4	2070	6700	5.3	37.8
21-1	R	6	2204	5450	4.4	33.3
21-2	R	6	—	—	—	—
22-1	GSL	2	2035	7050	10.8	65.5
22-2	GSL	2	2505	6950	10.6	64.5
23-1	GSL	4	1512	4750	5.7	40.6
23-2	GSL	4	1767	4350	6.3	42.6
24-1	GSL	6	1512	4700	6.1	39.4
24-2	GSL	6	1430	3775	7.1	42.5
25-1	GSL	10	1335	2825	4.8	38.4
25-2	GSL	10	1235	3050	4.6	42.6
26-1	GHL	2	2140	6725	10.2	53.7
26-2	GHL	2	2745	7075	6.5	42.6
27-1	GHL	4	2230	6950	7.1	46.0
27-2	GHL	4	2330	6550	7.6	45.7
28-1	GHL	6	2230	5950	6.4	40.5

TABLE NO. 24III

EFFECT OF COMMERCIALLY PREPARED EMULSIONS ON PRESSBOARD (CONT.)

Board No.	Size		Load in Grams	Modulus Lbs/Sq. In.	H_2O Absorption	
	Kind	%			% Gain ½ hr.	% Gain 24 hrs.
28-2	G.H.L.	6	2715	6150	6.3	38.5
29-1	G.H.L.	10	1918	6450	7.5	41.4
29 [illegible]	G.H.L.	10	3277	[illegible]	5.9	32.2

B-5 = Bennett's Prepared Size - 86 % Paraffin

B-1 = " " " 38 % "

B-18 = " " " 19 % "

G.S.L. = Soft Asphalt

G.H.L. = Hard "

A curve was plotted showing the relationship between per cent size and modulus of rupture. Asphalt affected the strength the least while the Bennett size No. 18 affected the strength the most. See Curve No. 1_{III}, page 146.

(f). Miscellaneous studies on beater sizing. A series of runs was made in order to determine the effect of pressure on absorption. The boards were made in both the large and small press. The small letter "b" denotes the board made in the small press. See Table No. 23_{III}, page 147.

In the majority of the runs the board made in the small press was stronger than the one made in the large press. The drying time was much shorter for the small board. No conclusion could be reached as to which pressure produced the best waterproofed board.

This next series of runs was made in order to determine the effect of sizing on expansion. The absorption was run on boards which were conditioned at bone dry, thirty per cent humidity, and one hundred per cent humidity. The boards were prepared exactly like those given in Table No. 22_{III}, page 139. Miller (27) completed this work on expansion using the above prepared boards. See Tables No. 25_{III} to 28_{III}, pages 149 to 152 inclusive.

The absorption was lower for the one hundred per cent humidity than for the thirty per cent. This would be expect-

Form E-5

CURVE NO. 1 III

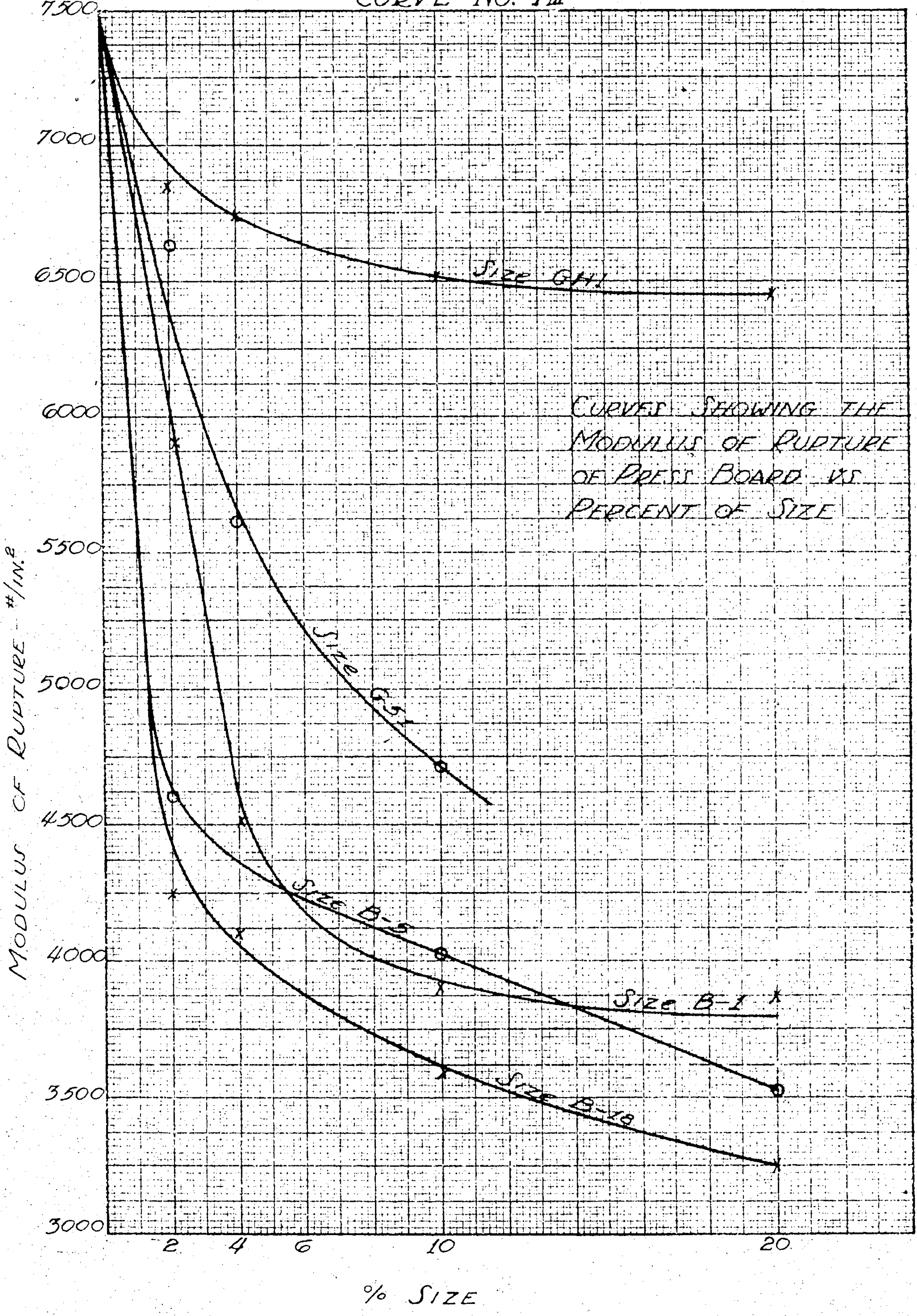


TABLE NO. 23 III

PRESSBOARD SIZE RUNS No.'s 300–325

No.	Sizing	Drying Time	Modulus	H_2O Absorption	
				% Gain ½ hr.	% Gain 24 hrs.
300		2 hrs 50 min	Too limber to test	59.4	103.5
301		"	"	59.3	105.3
302			4812	63.1	106.0
302b		45 min.	5125		
303			Too Limber to test	64.0	125.2
303b		45 min.	4100		
304		2 hrs. 50 min.	1630		
305			5010		
306b		40 min		18.9	75.4
306			3700	19.2	62.5
309			1434	16.3	58.2
310			1813	16.1	57.6
311			1321	32.0	62.8
315			1784	8.41	40.3
315b			2315	55.3	84.3
316	6% Alum 3% Rosin	2 hrs. 30 min.	2571	10.3	40.3
316b	"		1200	41.9	72.7
317	"	2 hrs 30 min.	3542	9.86	54.8
317b	"		3236	12.6	71.4
318	"		2605	34.8	83.9
318b	"		4114	40.1	64.2

TABLE NO. 23$_{III}$

PRESSBOARD SIZE RUNS No.'s 300-325 (Continued)

No.	Sizing	Drying Time	Modulus	H_2O Absorption	
				% Gain ½ hr.	% Gain 24 hrs.
319	6% Alum 3% Rosin	2 hrs 30 min.	2617	27.2	65.8
319b	"		3653	6.25	32.7
320	"		5377	15.2	52.8
320b	"		Too Limber to test	21.6	62.4
321	"		2664	16.1	62.3
321b	"		2154	6.89	37.6
322	"		2904	5.72	20.1
322b	"		2985		
323	"		2753	3.79	18.09
325	"	2 hrs 20 min.	4218	50.1	70.6

TABLE NO. 25_{III}

EXPANSION OF PRESSBOARD SIZED WITH ROSIN

NO.	NOTES ON PULP	% ALUM	% ROSIN	pH	% EXPANSION	ABSORPTION					
						BONE DRY		30% HUMIDITY		[illegible]0% HUMIDITY	
						½ HR.	24 HR.	½ HR.	24 HR.	½ HR.	24 HR.
1	3 Hr. H_2O Cook	3	3	4.7	.29	84.7	148.	80.2	100.5	64.5	97.0
2	"	3	3	4.7	.30	77.8	110.8	70.4	92.7	62.9	92.6
3	"	3	3	4.7	.20	85.3	130.2	80.5	99.0	45.9	77.0
4	48 Hr. H_2O Cook	0	0		.25	62.7	94.7	72.4	99.5	25.4	54.5
5	"	0	0		.20	110.0	129.3	93.0	112.8	27.8	56.8
6	"	0	0		.20	65.4	86.0	50.5	74.0	31.1	62.5
7	Mechanical Pulp	3	3	4.7	.19	57.0	116.0	59.4	86.9	42.1	62.8
8	"	3	3	4.7	.19	67.0	110.0	84.7	59.9	52.7	35.2
9	"	3	3	4.7	.24	53.4	87.0	117.0	65.2	54.2	41.2
10	"	0	0	5.2	.23	108.0	132.1	101.8	126.4	57.8	92.5
11	"	0	0	5.2	.23	92.2	114.0	101.8	128.2	55.5	90.2
12	"	0	0	5.2	.23	106.2	129.5	101.8	127.0	56.7	90.5
13	Masonite Pressboard				.25	6.7	31.8	5.8	27.3		
14	"				.25						
15	"				.21						

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TABLE NO. 26 III
EXPANSION OF PRESSBOARD SIZED WITH PARAFFIN

NO.	EMULSION	EMULSIFYING AGENTS	% SIZE	% ROSIN	% ALUM	pH	% EXPANSION	ABSORPTION					
								BONE D.		30% H.		100% H.	
								½ HR.	24 HR.	½ HR.	24 HR.	½ HR.	24 HR.
1	Paraffin	O.A. T.E.A.	4	0	4	4.9	.29	6.0	26.0	4.3	32.5	4.4	26.7
2	"	"	4	0	4	4.9	.35	4.9	27.2	5.7	33.9	3.2	10.2
3	"	S.A. – T.E.A.	4	0	4	4.5	.20	7.4	23.2	3.7	26.1	3.8	13.8
4	"	"	4	0	4	4.5	.23	6.3	27.9	5.4	38.1	4.8	17.5
5	"	"	1	0	3	4.1	.18	–	–	–	–	–	–
6	"	"	4	0	4	4.7	.25	8.2	46.5	9.7	42.5	5.8	87.8
7	"	"	8	–	–	–	.22	–	–	–	–	–	–
8	"	"	1	3	3	4.1	.28	9.3	32.9			4.1	19.9
9	"	"	1	3	3	4.1	.25	8.0	32.0			6.8	23.7
10	"	"	3	3	3	5.4	.30	5.7	25.7			10.0	26.2
11	"	"	3	3	3	5.4	.31	9.7	34.7			5.0	21.5
12	"	"	6	5	5	4.4	.24	7.3	33.1			3.5	13.8
13	"	"	6	5	5	4.4	.23	3.5	23.0			3.5	20.0

O.A. = Oleic Acid
T.E.A. = Triethanolamine
S.A. = Stearic Acid

TABLE NO. 27*ur*

EXPANSION OF PRESSBOARD SIZED WITH ASPHALT

NO.	EMULSION	M. PT. °F.	EMULSIFYING AGENTS	% SIZE	% ROSIN	% ALUM	pH	% EXPANSION	ABSORPTION					
									BONE D.		30% H.		100% H.	
									½ HR.	24 HR.	½ HR.	24 HR.	½ HR.	24 HR.
1	Asphalt	127	S.A. T.E.A.	4	0	3	5.0	.20	6.5	27.1	5.6	30.0	4.5	18.6
2	"	127	"	4	0	4	5.0	.29	6.8	24.4	4.1	24.4	3.2	14.1
3	"	147	"	4	0	3	5.2	.24	10.5	36.0	10.2	41.4	6.5	27.2
4	"	147	"	4	0	4	5.2	.24	6.6	32.9	9.4	32.4	4.5	13.6
5	"	242	"	4	0	3	5.3	.24	8.2	33.9	9.8	32.2	3.7	12.9
6	"	HM	"	4	0	4	4.6	.30	5.3	26.8	5.0	38.5	5.1	22.0
7	"	HM	"	4	0	4	4.6	.36	6.2	26.7	6.1	26.6	4.3	14.2

S.A. = Stearic Acid
T.E.A. = Triethanolamine

TABLE NO. 28 III
EXPANSION OF PRESSBOARD SIZED WITH ASPHALT

NO.	EMULSION	M. PT. °F	EMULSIFYING AGENTS	% SIZE	% ROSIN	% ALUM	pH	% EXPANSION	ABSORPTION					
									BONE D.		30% H.		100% H.	
									½ HR.	24 HR.	½ HR.	24 HR.	½ HR.	24 HR.
1	Asphalt	127	Rosin, T.E.A	4	4	4	4.3	.24	6.9	28.2	13.4	53.0	9.7	48.8
2	"	127	"	4	4	4	4.2	.22	6.9	25.0	18.9	66.5	15.7	47.6
3	"	147	"	4	4	4	5.2	.23	5.6	32.3	10.2	54.4	6.4	51.2
4	"	147	"	4	4	4	5.2	.25	6.9	31.9	9.2	40.0	6.0	79.5
5	"	L.M.	"	4	4	4	4.2	.21	6.5	26.1	9.5	51.0	5.9	44.4
6	"	L.M.	Rosin, soap	4	4	4	5.2	.24	6.6	32.9	9.4	32.4	4.5	[illegible]3.6
7	"	242	"	4	4	4	4.6	.21	9.5	47.4	18.6	65.0	5.8	39.4
8	"	242	"	4	4	4	4.6	.22	6.4	32.2	18.8	58.4	7.5	45.4
9	Pitch	H.M.	Rosin, soap, T.E.A.	4	4	4	4.2	.24	6.5	21.1	11.9	63.7	7.1	48.7
10	"	H.M.	Soap, S.A. T.E.A.	4	0	5	4.0	.29	7.2	33.5	7.4	46.9	5.3	35.2
11	"	H.M.	"	4	0	5	4.0	.32	18.4	45.2	8.3	39.6	5.0	19.0
12	Asphalt	127	O.A.-T.E.A.	4	0	5	4.2	.20	9.7	43.6	10.7	40.5	4.6	24.6
13	"	127	"	4	0	5	4.2	.23	9.3	39.4	8.1	33.6	5.8	24.7
14	Asphalt Para.		S.A.-T.E.A.	12	—	—	—	.19	—	—	—	—	—	—

Pitch is a very high melting asphalt.
T.E.A. — Triethanolamine
S.A. — Stearic
O.A. — Oleic acid

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ed since a board at one hundred per cent humidity all ready holds more water than one at thirty per cent. Very little difference was noticed in the expansion of the boards sized by different means. Boards sized with asphalt and emulsified with stearic acid showed the least expansion, 0.19 per cent, while the board sized with paraffin and emulsified with oleic acid and tri-ethanolamine gave the highest expansion, 0.32 per cent.

The Bennett Sizing Laboratories of Cambridge, Mass., performed some interesting studies on various pressboards. Since they performed their absorption tests by a different method, it is impossible to compare their values with any of the preceding results. Lower moisture absorptions were secured by using their prepared size. The expansion was much less for boards sized with paraffin and rosin than for rosin alone. See Table No. 29_{III}, page 154.

(2). Surface sizing. The following studies were made without adding any size in the beater. Various oils and waxes were added to the surface of the board just before pressing. The edges of the boards were not coated, therefore, most of the moisture entered through the edges. Several methods (6, 7) of testing surface size were tried but in no case could dependable results be secured. Therefore, all surface sized boards were immersed in order to secure absorp-

TABLE NO. 29 III

PHYSICAL TESTS ON COMMERCIAL PRESSBOARD[1]

NO.	MOISTURE		EXPANSION IN 64THS OF AN IN.		SHRINKAGE IN 64THS OF AN IN.		MOISTURE ABSORPTION GMS./SQ. FT. IN 48 HRS.	TIME TO REACH MAX. ABSORPTION (DAYS)	TIME OF DRYING BACK TO ORIG. WT. (DAYS)	SHRINKAGE UNDER ORIG. SIZE	
	ORIGINAL	AFTER ABSORPTION	LENGTH	WIDTH	LENGTH	WIDTH				LENGTH	WIDTH
A	5.6	15.6	14	5	22	11	193	2	2	8	6
B	5.5	14.9	12	4	20	8	138	1	1	8	4
C	6.5	13.0	8	6	14	10	128	4	1⁻	6	4
D	2.6	11.1	8	8	5	7	88	3	*	*	*
E	3.7	10.2	4	4	6	5	88	4	2½	2	1
F							114				
G							136				

* Board could not be dried back to original weight.
A is pressboard rosin sized, groundwood screenings.
B " " " " " and sulfite screenings.
C " " " " "
D is laminated board sized with Bennett No. 18 size, groundwood screenings.
E " " " " " " " " " " "
F " pressboard rosin sized, groundwood screenings.
G " " " " " and sulfite screenings.
1 Results from the Bennett sizing laboratories

tion values. In some cases the edges were separately coated with paraffin.

(a). Paraffin oil. Paraffin oil was used in the first series. The absorption was about half that of the blank but the modulus of rupture was decidedly weakened. Boards pressed at 150° Centigrade gave better absorption values than those pressed at 130°. The modulus was also higher for the 150° boards. See Table No. 30_{III}, page 156.

(b). Parowax. Parowax did not seem to injure the strength as much as did the paraffin oil. Boards pressed at 150° Centigrade gave the best results of waterproofing, while the boards pressed at 130° gave the poorest. See Table No. 31_{III}, page 157.

(c). Halowax. Halowax seemed to give no waterproofing to the boards whatsoever for the blank absorbed less water than the treated boards. Probably this particular sample of Halowax was inferior to the standard product for it should have waterproofed the board. Halowax did not injure the strength as much as did parowax and paraffin oil. See Table No. 32_{III}, page 158.

(d). Bakelite varnish. Small samples of pressboard six inches square were painted with Bakelite varnish and allowed to stand twenty-four hours. The boards were then pressed in the small press at various temperatures and pres-

TABLE NO. 30 III

SURFACE SIZING OF PRESSBOARD WITH PARAFFIN OIL

NO.	TEMP. OF PRESSING °C.	MODULUS (LBS/SQ.IN.)	DENSITY (LBS./CU.FT.)	% MOISTURE ABSORPTION	
				½ HR.	24 HRS.
1	130°	1480	60.2	7.3	58
2		1150	58.1	9.1	53.5
3		186	60.3	8.4	44
4		2390	60.8	7.8	36.6
5		2760	61.0	9.4	48
6		2880	60.9	9.6	51
7	150°	2220	68.3	10.9	38
8		2240	68.2	11.9	41
9		2750	69.3	7.8	33
10		2640	69.0	8.4	33
11		2960	69.7	8.4	37
12		2640	69.1	7.8	39
13	Blank 140°	4280	61.2	13.40	94.9
14		3940	59.9	12.60	93.6
15		3960	61.8	14.20	95.8
16		4930	62.4	13.7	94.2
17		4940	64.0	12.3	92.6
18		5250	66.4	11.8	93.4
19		3670	64.9	10.9	97.4
20		4030	64.6	13.2	94.7

TABLE NO. 31_{III}

SURFACE SIZING OF PRESSBOARD WITH PARAWAX

NO.	TEMP. OF PRESSING °C.	MODULUS (LBS./SQ.IN.)	DENSITY (LBS./CU.IN.)	MOISTURE ABSORPTION	
				½ HR.	24 HRS.
1	130°	3470		5.72	35.0
2	↓	2480	60.2	6.00	37.5
3		2630		7.50	41.0
4		3120	61.4	5.50	35.0
5		2975		8.40	38.0
6		2600		7.80	39.0
7		3200	62.2	4.40	25.8
8	↓	1925		9.20	38.0
9	140°	3400	63.4	7.30	29.4
10	↓	2540		6.10	39.8
11		2400	62.7	5.90	44.5
12		3100		5.20	29.1
13		3220		6.90	28.4
14		3420	63.2	7.70	32.5
15	↓	3300		6.60	32.7
16	150°	2980	63.7	5.40	21.4
17	↓	3400		5.50	23.2
18		3200	63.9	4.27	19.0
19		3080		4.10	19.5
20		3060		5.10	22.8
21	↓	4000	64.2	4.40	23.9

TABLE NO. 32$_{III}$

SURFACE SIZING OF PRESSBOARD WITH HALOWAX

NO.	TEMP. OF PRESSING (°C.)	MODULUS (LBS./SQ. IN.)	DENSITY (LBS./CU.IN.)	MOISTURE ABSORPTION	
				% ½ HR.	% 24 HRS.
1	Blank 150°	7610	65.0	44	53.6
2		6860	61.5	68	95.0
3		7370	66.3	45.7	85.
4	Blank 140°	6640	63.7	59	128
5		5810	62.4	67	101
6	Blank 130°	6140	60.1	46	92
7		6840	61.1	65	97
8	140°	5250	58.0	58	91
9		6010	64.6	56	93
10		5100	63.5	41	90.5
11		5150	63.4	35	87
12		6100	64.7	34.8	87
13	150°	7150	63.8	31.4	80
14		6250	66.0	28.6	77
15		6200	59.1	48.5	95
16		6100	62.7	48.5	83.5

sures. The boards had to be placed between two highly polished plates in order to secure a smooth glossy finish. The edges were not waterproofed completely. The heat and pressure set the varnish on the surface but not on the edges. In running the moisture absorption the edges were treated with paraffin but this still did not check the moisture. See Table No. 33_{III}, page 160.

The strength of the boards was increased slightly by the addition of the Bakelite varnish. The best results were secured by pressing the painted boards between a temperature of one hundred and sixty to one hundred and seventy degrees Centigrade for ten minutes. Pressure made very little difference. Very low values for moisture absorption were secured in some cases when the Bakelite varnish was set completely on the edges. After moisture once entered the edges it crept under the surface of the varnish. The moisture destroyed the appearance of the board.

TABLE No. [illegible]

SURFACE SIZING OF PRESSBOARD WITH BAKELITE VARNISH

RUN NO.	MODULUS LBS/SQ.IN	MOISTURE ABSORPTION ½ HOUR	MOISTURE ABSORPTION 24 HOURS	DENSITY LBS/CU.IN	TEMP. (DEG)	TIME (MIN.)	REMARKS
1	8420	57.00	18.5	58.0			Blank
2	7210	59.00	87.0	58.0			"
3	7160	55.00	80.0	58.0			"
4	7170	75.00	94.5	55.3			"
5	7630	56.00	89.0	71.0			"
6	7290	58.50	84.0	71.0			"
7	7700	12.00	64.0	62.5	170-180	15	Edges not covered
8	5550	28.00	75.0	57.0	"	"	"
9	8190	14.90	68.0	61.1	"	"	"
10	8900	4.80	51.0	71.9	"	10	"
11	8300	12.70	57.5	64.2	"	"	"
12	7650	12.90	61.5	64.5	"	"	"
13	8100	12.00	63.5	67.3	160-170	15	"
14	7300	17.60	17.6	56.0	"	"	"
15	10500	13.60	13.6	65.6	"	10	"
16	8200	6.70	6.7	64.5	"	"	"
17	9150	6.40	6.4	60.0	"	15	Paraffine on edges
18	7350	11.80	73.5	51.5	150-160	10	"
19	7600	3.40	72.0	61.0	"	"	"
20	7400	1.16	73.0	56.5	140-150	15	"
21	7200	9.05	74.0	65.5	120-130	10	"
22	9700	7.25	78.0	69.0	"	"	"
23	8800	3.80	71.0	62.5	110-120	15	"
24	8200	2.70	70.0	64.0	120-130	10	"
25	9600	0.60	60.0	73.0	"	15	"

IV

SUMMARY AND CONCLUSIONS

A. Insulation Board

The tests made on rosin extraction showed Nuwood and Insulite to contain the most rosin while Celotex and cooked Maizewood contained the least. The high values for the former two boards were probably due to the rosin content of the raw materials used. Even though Nuwood did have a high rosin content the moisture absorption for this board was higher than any of the other boards. Insulite gave the lowest moisture absorption.

Masonite yielded the lowest per cent of ash, a low figure of 0.27 per cent was secured. The two Maizewood boards yielded a very high per cent of ash, 4.65 per cent for the mechanical board and 8.00 per cent for the cooked. These high figures would lead one to believe that the pulp was not washed free of dirt. The pulp for both boards was washed the same number of times. The cooked pulp should have been washed more than the mechanical pulp for it is much easier to remove the dirt from the latter. Boards made from wood showed much less ash than boards made from other materials which may have been commingled with dirt.

The commercial boards, which yielded high ash, also yielded high silica. The ash from cooked Maizewood proved to be 75.8 per cent silica. Though Insulite did have a higher ash content than Masonite the former contained a higher per cent of silica than the latter. The results showed the ash of Insulite to contain more oxides of aluminum and iron than any of the other boards. Celotex contained more iron oxide but not as much aluminum oxide as the majority of the boards did. The boards made from materials other than wood seemed to contain less aluminum oxide than those made from wood.

The mechanical board made by Maizewood proved to be the highest in insulating value. It was the weakest board but this would be expected for it was not pressed as hard as the others. Insulite was just about twice as strong as the other boards. The majority of the boards tested around three hundred and fifty pounds per square inch.

At laboratory conditions, Masonite seemed to expand more in both length and width. Maizewood expanded less than any in width. Celotex lost the most moisture during the eighteen days. The moisture content of Masonite, as received, was lower than any of the boards.

Celotex showed the least amount of expansion in length and width both at the hundred and the seventy per cent humidities. Little difference was noticed in the expansion of the ~~un~~sanded Maizewood and the unsanded Maizewood boards at seventy per cent humidity but apparently, sanding increased the expansion at the higher humidity. Insulite expanded less than Maizewood at the seventy per cent humidity but no difference was noticed at the higher humidity.

No appreciable change in length or width was noticed on finished boards during the first hour after they were removed from a constant temperature oven. The boards attained their original length and width after standing twenty-four hours at a temperature of 80° F. and thirty per cent relative humidity.

Maizewood lath expanded 0.78 per cent in length and 0.69 per cent in width when immersed in water for twenty-four hours. The lath contracted 0.38 per cent in length and 1.0 per cent in width after drying five days at 80° F. and thirty per cent relative humidity. Similar results were secured for the second immersion.

Maizewood lath which were nailed on studding failed to show any change in length when placed at the above conditions for thirty days. The lath expanded 0.3 per cent in width when placed at 80° F. and thirty per cent relative humidity.

Boards containing from four to six per cent moisture seemed to expand and contract less when removed from the dryer than did boards containing a higher or lower per cent moisture.

Removing boards from the dryer at varying percentages of moisture seemed to have little effect on density, strength, and moisture absorption.

Boards containing high percentages of newsprint expanded the same amount as boards containing less.

Temperature seemed to play very little part in expansion at each humidity. No difference was noticed from a low temperature of twenty-two degrees to a high temperature of forty-one degrees. The board expanded in length, width and thickness for every increase in humidity. Maizewood expanded more in length than any of the boards but hardly any difference was noted in width, thickness and weight.

Boards could not be fireproofed by adding various amounts of sodium silicate to the pulp in the beater. The same results were secured by using cornstalk cook liquor, asbestos, and several ammonium salts.

Boards could be fireproofed by applying chemical solutions to the surface of the finished boards. Ammonium phosphate seemed to give the best results.

Potassium salts did fireproof the boards to some extent but not to such an extent as needed in industry. The boards did not blaze as readily as did the blank sample but they continued to glow for some time. Potassium acid sulphate seemed to improve the waterproofing of the boards as well as improve the strength. Potassium hydroxide injured the boards more than any other reagent used.

Maizewood was fireproofed one hundred per cent by adding a commercial fireproofing compound to the pulp in the mixing tanks. The boards were not sized correctly for the moisture absorption was very high.

Commercial wall boards will mold if they are placed at a warm, moist atmosphere but not before fifty to sixty days. The edges of the boards showed signs of molding before the surfaces. Boards treated with small concentrations of zinc chloride, copper sulphate, and mercuric chloride failed to show signs of molding at the end of ten weeks.

Boards treated with sodium hydroxide failed to mold while boards treated with hydrochloric acid did mold. Asphalt emulsions prevented molding. Paraffin emulsions prevented molding if the entire surface was covered. Boards treated with Barrett's resin molded in a very short time.

B. Refrigeration Board

Fermentation seemed to add to the strength without greatly affecting the density. Pulp treated with caustic was unsatisfactory for refrigeration boards. The lowest density secured for this type of board was five and two-tenths pounds per cubic foot. Little difference was found in the density of boards made from either mechanical or water cooked pulp.

Refrigeration boards could not be made from the nodes of the cornstalk. Light weight boards could be produced from leaves and husks if they were washed free from dirt. Boards produced from the cortex were strong and clean but not very light weight.

A very good grade of pith could be separated from the outer fiber by the hydration method. Air separation was tried but the results did not prove successful. Eighty per cent of the pith could be removed without securing much cortex. The cortex could be used for paper, pressboard or Maizolith.

Very little difference in density was discovered between the pith separated by hand and that separated by machine. Refining the pith in the jordan increased the strength and improved the texture of the board. Cooking the pith with chemicals improved the strength but increased the density.

Refrigeration board could not be dried in air commercially due to the long time required for drying.

Boards dried in the steam oven were of good quality. This method of drying was also expensive for the efficiency of the dryer was only 24.9 per cent.

Vacuum drying increased the efficiency. This method still required a long time for drying.

Boards were dried in the Proctor and Schwartz dryer more rapidly than in any other dryer used. The boards did not warp as badly as in the first two methods.

Electricity proved to be very expensive for drying refrigeration boards.

Little difference was found in the conductivity values for pith separated by hand and that separated by machine. The stalks must be washed free from dirt if low conductivities are desired. The conductivity of pith board is much lower than the regular cork board. Coating the refrigeration board with alcogel seemed to improve the insulation properties of the board, as well as, reduce the moisture absorption.

The moisture absorption of pith board was reduced to 95 per cent without affecting the density or conductivity. Such materials as asbestos, sodium silicate, sodium flouride, ammonium flouride, and cornstalk adhesive were tried as possible fireproofing agents as well as waterproofing agents. Cornstalk adhesive gave the best results of this series.

Refrigeration board was not fireproofed by adding chemicals to the pulp in the beater. Samples coated with sodium silicate were fireproofed fairly well.

A very light insulating material was produced from the foam and pulp secured by adding rosin to fermented pulp or adding large amounts of rosin to regular pulp. The amount of foam probably could be increased by the addition of glucosides. When this foam was dried a very light board was produced which had good insulating properties.

C. Pressboard

Stronger pressboard was made from cooked pulp than from mechanical pulp.

One pass through the rod mill and twelve hours of beating gave a good mechanical board. Cooked pulp required a much shorter beating time.

Pressboard was produced in a much shorter time by using the rod mill and claflin. Two times through the rod mill and twenty minutes of clafling gave the strongest mechanical boards. Cooked pulp required one pass through the rod mill and five to six minutes refining. Fermentation increased the strength of both the mechanical and cooked pulp.

The strongest boards were produced from pulp containing 66 per cent or more moisture.

The mat of pulp still contained 54.5 per cent moisture after it was pressed at eight hundred and seventy-four pounds per square inch.

Thirty minutes was a sufficient length of time for pressing boards of one-eighth inch thickness.

The maximum strength of pressing was found to be between four hundred and seventy-five and five hundred and thirty pounds per square inch. Very little difference in strength was noticed for boards pressed at such high pressures from those pressed at one hundred and forty pounds.

The temperature of the press when the boards were inserted seemed to play very little part to the strength of the board.

The best range of rosin and alum sizing seemed to be between a ratio of 0.6 to 1.0, that is, six-tenths as much rosin as alum. Too high a per cent rosin injured the strength of the board.

The paraffin emulsions gave very good waterproofing.

Sodium alginate proved to be a very poor sizing material.

Asphalt and pitch did not waterproof the board as well as paraffin did. The strength was decreased in every case where these three emulsions were used. Bennett Size No. 5 gave the best sizing results for the whole series.

The moisture absorption for boards that were conditioned at one hundred per cent humidity was lower than those conditioned at thirty per cent humidity.

Boards which were sized with asphalt and emulsified with stearic acid showed the least expansion, 0.19 per cent, while the board sized with paraffin and emulsified with oleic acid and tri-ethanolamine gave the highest expansion, 0.32 per cent.

The Bennett laboratories furnished some results which showed their size to be much better for waterproofing boards than rosin alone. The expansion was greater for rosin sized boards also.

Surface sizing proved to be almost worthless. In most every case the strength was weakened decidedly. Halowax seemed to give no waterproofing qualities. The Bakelite varnish gave a good finish to the board but it would take up small quantities of water. After water was once in the board the surface was ruined.

These foregoing facts tend to prove that, first, Maizewood compares favorably with the other commercial wall boards, second, that the pith of the corn plant furnishes an insulating material of low conductivity, and third, that a good grade of pressboard can be produced which will be suitable to compete with the other pressboards on the market.

V

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